PB-223 579

EQUIMOLAR NO-NO2 ABSORPTION INTO MAGNESIA SLURRY: A PILOT FEASIBILITY STUDY

W. Downs

Babcock and Wilcox Company

Prepared for:

Environmental Protection Agency

29 November 1971

DISTRIBUTED BY:

NTIS
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

EPA-650/2-73-015

PB 223 579
4653

Babcock & Wilcox

EQUIMOLAR NO-NO_2 ABSORPTION INTO MAGNESIA SLURRY--A PILOT FEASIBILITY STUDY

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

RESEARCH AND DEVELOPMENT DIVISION
ALLIANCE RESEARCH CENTER

SPONSORED BY
ENVIRONMENTAL PROTECTION AGENCY

115

BIBLIOGRAPHIC DATA SHEET

1. Report No. EPA-650/2-73-015

2.

3. Recipient's Accession No. PB-223 579

4. Title and Subtitle
Equimolar NO-NO2 Absorption into Magnesia Slurry -- A Pilot Feasibility Study

5. Report Date November 29, 1971

6.

7. Author(s)
W. Downs

8. Performing Organization Rept. No. 4653

9. Performing Organization Name and Address
The Babcock & Wilcox Company
Research and Development Division
Alliance Research Center
Alliance, Ohio

10. Project/Task/Work Unit No. Order 4193-01

11. Contract/Grant No. 68-02-0022

12. Sponsoring Organization Name and Address
ENVIRONMENTAL PROTECTION AGENCY
Research Triangle Park, North Carolina 27711

13. Type of Report & Period Covered

14.

15. Supplementary Notes

16. Abstracts

The purpose was to investigate the feasibility of absorption of equimolar concentrations of NO_x into MgO slurry on a 1500 cfm wet scrubbing pilot plant. A wet scrubbing pilot plant consisting of several scrubbers was modified by the inclusion of an additional scrubber to enable series scrubbing of fly ash, sulfur dioxide, and finally nitrogen oxides. Gaseous nitrogen dioxide was injected into the flue gas following the SO_2 scrubber but before the NO_x scrubber. Seventeen tests were performed to evaluate parameters including the liquid-to-gas ratio, the ratio of NO_2 to NO, slurry concentration, stoichiometry, and gas flow rate. NO_x absorption was very poor for all conditions tested. The absorption is estimated to be less than 10%. The results are obscured by large variance in the NO_x measuring techniques. SO_2 absorption in the NO_x scrubber was dependent upon the liquid-to-gas ratio and varied from 86% to 98.3%. Deposition on the underside of the first tray of the SO_2 scrubber was observed. NO_x absorption with equimolar concentrations of NO and NO_2 into MgO slurry is not feasible in the apparatus tested. It is probably unfeasible in any practical gas-slurry contacting apparatus. NO_x absorption into soluble alkalis may be feasible and would best be done in packed towers.

17. Key Words and Document Analysis. 17a. Descriptors

Air pollution
Nitrogen oxide (NO)
Nitrogen dioxide
Absorption
Magnesium inorganic compounds
Feasibility
Scrubbers
Liquids
Gases
Flow rate
Flue gases
Sulfur dioxide
Deposition
Air pollution control equipment

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group 13B

18. Availability Statement
Unlimited

19. Security Class (This Report) UNCLASSIFIED

20. Security Class (This Page) UNCLASSIFIED

21. No. of Pages 116

22. Price $7.75

FORM NTIS-35 (REV. 3-72)

THIS FORM MAY BE REPRODUCED

USCOMM-DC 14952-P72

EQUIMOLAR NO-NO_2 ABSORPTION INTO MAGNESIA SLURRY— A PILOT FEASIBILITY STUDY

PROJECT SPONSORED BY ENVIRONMENTAL PROTECTION AGENCY
ORDER 4193-01
RESEARCH CENTER REPORT 4653
BY: W. DOWNS
NOVEMBER 29, 1971

THE BABCOCK & WILCOX COMPANY
RESEARCH AND DEVELOPMENT DIVISION
ALLIANCE RESEARCH CENTER
ALLIANCE, OHIO

ia

COPY NO. ______

THE BABCOCK & WILCOX COMPANY
RESEARCH AND DEVELOPMENT DIVISION
ALLIANCE RESEARCH CENTER
ALLIANCE, OHIO

EQUIMOLAR NO-NO_2 ABSORPTION INTO MAGNESIA SLURRY— A PILOT FEASIBILITY STUDY

By: W. Downs

ABSTRACT

Purpose

The purpose of this project was to investigate the feasibility of absorption of equimolar concentrations of NO_X into MgO slurry on a 1500 cfm wet scrubbing pilot plant.

Summary

A wet scrubbing pilot plant consisting of several scrubbers was modified by the inclusion of an additional scrubber to enable series scrubbing of fly ash, sulfur dioxide, and finally nitrogen oxides. Gaseous nitrogen dioxide was injected into the flue gas following the SO_2 scrubber but before the NO_X scrubber. Seventeen tests were performed to evaluate parameters including the liquid-to-gas ratio, the ratio of NO_2 to NO, slurry concentration, stoichiometry, and gas flow rate.

Results

NO_X absorption was very poor for all conditions tested. The absorption is estimated to be less than 10%. The results are obscured by large variance in the NO_X measuring techniques. SO_2 absorption in the NO_X scrubber was dependent upon the liquid-to-gas ratio and varied from 86% to 98.3%. Deposition on the underside of the first tray of the SO_2 scrubber was observed.

Conclusions

NO_X absorption with equimolar concentrations of NO and NO_2 into MgO slurry is not feasible in the apparatus tested. It is probably unfeasible in any practical gas-slurry contacting apparatus.

NO_X absorption into soluble alkalis may be feasible and would best be done in packed towers.

Recommendations

MgO slurry should be removed from those bases being considered for aqueous NO_X absorption.

Work should continue on the feasibility evaluation of soluble bases for this system.

Research Center Report 4653
Order 4193-01
November 29, 1971
Equimolar NO_X-MgO Absorption
Project Sponsored by Environmental
Protection Agency

TABLE OF CONTENTS

Page
1.0 INTRODUCTION ---------- 1-1
2.0 PILOT PLANT EQUIPMENT ---------- 2-1
  2.1 Coal Preparation ---------- 2-1
  2.2 Burner and Furnace ---------- 2-1
  2.3 Fuel ---------- 2-2
  2.4 Wet Scrubbing Apparatus ---------- 2-2
    2.4.1 Particulate Scrubbing System ---------- 2-2
    2.4.2 Floating Bed Absorber ---------- 2-3
  2.5 Induced Draft Fan Section ---------- 2-4
  2.6 NO_X Scrubber and Components ---------- 2-4
    2.6.1 NO_2 Injection System ---------- 2-4
    2.6.2 NO_X Scrubber ---------- 2-5
  2.7 Overall Pilot Plant Schematic ---------- 2-6
3.0 TEST APPARATUS AND PROCEDURES ---------- 3-1
  3.1 Plant Operating Test Procedure ---------- 3-1
  3.2 Flue Gas Analysis ---------- 3-2
    3.2.1 General Analysis ---------- 3-2
    3.2.2 NO_X Analysis ---------- 3-2
  3.3 Liquid Analyzer ---------- 3-7
4.0 RESULTS ---------- 4-1
  4.1 Overall Results ---------- 4-1
    4.1.1 Particulate Scrubber ---------- 4-1
    4.1.2 FBA ---------- 4-1
  4.2 NO_X Scrubber Results ---------- 4-2
    4.2.1 NO_X Absorption ---------- 4-2
    4.2.2 SO_2 Absorption ---------- 4-3
5.0 DISCUSSION ---------- 5-1
6.0 CONCLUSIONS ---------- 6-1
7.0 RECOMMENDATIONS ---------- 7-1
REFERENCES ---------- R-1
APPENDIX A, SALTZMAN ANALYTICAL PROCEDURE ---------- A-1
APPENDIX B, COMPUTER OUTPUT ---------- B-1

TABLE OF CONTENTS

List of Tables

Table Page

2.1 Fuel Analysis ---------- 2-7

3.1 Sodium Nitrite Equivalence for Mixtures of NO and NO_2 ---------- 3-8

4.1 Analysis of Deposit Samples ---------- 4-4

4.2 Parameter Study Specifications ---------- 4-5

4.3 Summary of Results ---------- 4-6

List of Figures

Figure Page

2.1 Magnesia Base Slurry Scrubbing Pilot Plant ---------- 2-8

2.2 Basic Combustion Test Furnace ---------- 2-9

2.3 Particulate Scrubbing System ---------- 2-10

2.4 Particulate Scrubbing System ---------- 2-11

2.5 Floating Bed Absorber ---------- 2-12

2.6 Floating Bed Absorber ---------- 2-13

2.7 Slurry Entrainment Separator Section ---------- 2-14

2.8 NO_2 Injection System ---------- 2-15

2.9 NO_X Scrubber Dimensions ---------- 2-16

2.10 NO_X Scrubber ---------- 2-17

2.11 NO_X Scrubber and Leach Bed ---------- 2-18

2.12 Pilot Plant Flow Schematic ---------- 2-19

3.1 SO_2 Sampling System ---------- 3-9

3.2 NO_X Sampling System ---------- 3-10

3.3 NO Oxidation Rate in Air ---------- 3-11

3.4 NO Oxidation Rate in Flue Gas ---------- 3-12

3.5 Equilibrium HNO_2 Concentrations ---------- 3-13

4.1 Deposition on Underside of First FBA Stage ---------- 4-7

4.2 SO_2 Absorption in NO_X Scrubber ---------- 4-8

5.1 Geometry Assumed for NO_X Absorption ---------- 5-8

5.2 Predicted NO_X Absorption in Test Apparatus ---------- 5-9

5.3 Process Flow Schematic ---------- 5-10

1.0 INTRODUCTION

NO_X removal from power plant effluents by wet scrubbing is one of the approaches being considered by the Office of Research and Monitoring (ORM) of the Environmental Protection Agency (EPA) in its overall NO_X program. In response to the suggestion from several sources including the recommendation submitted to ORM by The Babcock & Wilcox Company under Contract CPA-22-69-162, the feasibility of absorbing equimolar concentrations of NO and NO_2 into magnesia slurry was undertaken. This work is the outgrowth of a study of wet scrubbing of pulverized coal generated flue gas for the purpose of removing particulate matter and sulfur dioxide in a 1500 cfm pilot plant. As part of that study it was shown to be unfeasible to absorb equimolar NO_X and SO_2 simultaneously. However it was suggested that possible nitrogen oxides could be absorbed into magnesia in the scrubber following the SO_2 scrubber. This report presents the results of that work under Contract 68-02-0022.

2.0 PILOT PLANT EQUIPMENT

The pilot plant equipment used for these tests is a self-contained facility which includes coal preparation equipment, a coal-fired furnace, and a wet scrubbing pilot plant. Most of this equipment has been previously described.(1) Only the modifications and additions will be discussed in detail. A pictorial drawing of the pilot facility is shown in Figure 2.1.

2.1 COAL PREPARATION

Coal preparation involves transporting 1/2" mesh coal from the storage bunker to the pulverizer, pulverizing the coal, and transporting it to a storage hopper at the pilot plant. From there the coal is removed by a screw and conveyed to the furnace by the primary air.

The storage bunker is used primarily to supply the heating plant for the Research Center. The pulverizer used during this test program differs from the used on previous tests.(2) A Schutz-O'Neill Air Swept pulverizer Model 22-WJ superfine pulverizer was installed in early 1971 and was used exclusively for these tests.

2.2 BURNER AND FURNACE

The pulverized coal burner is a B&W cell-type circular burner with a natural gas lighter. This lighter is operated continuously during coal firing to help maintain stable ignition.

The furnace, Figure 2.2, consists of a horizontal cylinder 8 feet in length by 4-1/2 feet in diameter. This forms the actual combustion chamber. The walls of the furnace are formed by a water jacket, which dissipates heat by the production of nonpressurized steam. The inside walls are not covered with refractory.

To maintain stable ignition, the pulverized coal must be fired with preheated air. This air is supplied by a forced draft fan and preheated by two gas-fired air heaters capable of heating 10,000 lb/hr air to a temperature of 1000°F. The heat release of the furnace averages about six million Btu/hr.

Combustion gases pass from the furnace proper through three tube banks that cool the flue gas to approximately 450°F. All tubes are 1-1/2-inch O.D. on 2-1/2-inch centers with exception of the first six rows of tubes which are on 5-inch centers. Behind each tube bank is a duct permitting flue gas recirculation to the burner. See Figure 2.2. This feature, however, was not used during the tests. Flue gas leaving the tube bank passes through a transition piece to a 15-inch-diameter vertical stack. Gas flow to the scrubbing system is taken from the side of this stack. The vertical stack ends at a relief valve. The relief valve is pneumatically operated and is automatically activated during a test if furnace pressure becomes too great. The relief valve can also be operated manually from the control panel and is used during startup and shutdown operations.

The furnace control panel is fully equipped to monitor and control the furnace pressures. A 12-point Speedomax recorder provides a continuous check of the temperatures within the furnace and ancillary components. Oxygen concentration of the flue gas is continuously monitored by a Bailey O_2 Analyzer Model A57.

Located on top of the furnace (Figure 2.2) is the steam drum, a steel cylinder 4-foot diameter by 6-foot long. This drum supplies water to the furnace water jacket and acts as a steam-water separator for venting the steam to atmosphere.

2.3 FUEL

Two fuels were used cocurrently during the tests, pulverized coal and natural gas. Pulverized coal was the main fuel while natural gas was used in the lighter and accounted for about 4% (thermal) of the fuel used. A number of coal analyses were run and the results reported in Table 2.1. A typical natural gas analysis obtained from the Ohio Fuel Company is also shown in Table 2.1.

2.4 WET SCRUBBING APPARATUS

2.4.1 Particulate Scrubbing System

Flue gas leaving the furnace passed through the water tube section to the particulate venturi and cyclone, see Figures 2.3 and 2.4. As the gas entered the venturi throat, its velocity was greatly increased. It is here that the fly ash slurry spray was introduced, just slightly ahead of the throat. The fly ash particles traveling at high velocity impacted upon the slower moving slurry droplets.

The fly ash slurry was separated from the flue gas in the cyclone separator. The flue gas and slurry entered the cyclone tangentially, spinning the slurry to the walls while the gases moved toward the center and out the top. The slurry moved from the cyclone into the sump located immediately below.

The slurry was pumped from the sump and recirculated back to the venturi spray nozzle. To maintain the desired composition, part of the slurry was discarded. Fresh water previously treated by a zeolite bed was added directly to the sump and through the pump seal. Approximately 25 gal/min of slurry were recirculated through the spray nozzle, and about 9 lb/min were discarded as particulate product.

The particulate venturi spray nozzle flow was controlled by the pump and pinch valve. A pneumatically controlled pinch valve (Red Valve Company) regulated the amount of "short circuit" recirculation through the pump and valve loop. Closing the pinch valve forced more slurry through the spray nozzle. This arrangement was used instead of the normal control method via a gate or glove valve, because solids tend to collect behind the seat, thereby restricting flow. The product flow rate was controlled by an overflow weir in the sump which dumped slurry into a 55-gallon drum.

At the gas outlet from the particulate cyclone, the vortex spin was eliminated by a flow straightener. This cross-shaped member 10 inches long by 10 inches in diameter was placed in the cyclone gas exit duct.

A gas sampling probe used for both NO_X sampling and SO_2 sampling is positioned 4 inches downstream from the dust sampling connection. The probe includes a 6-inch long 1-3/4-inch pipe welded flush to the duct wall and a 1/8-inch glass tube located concentrically in this pipe. The pipe provides a "quiescent" zone in which the gas flow to the glass probe is relatively slow. This minimizes the possibility of slurry carryover from the cyclone entering into the glass tubing which in turn could result in SO_2 and NO_X sampling errors due to scrubbing of the gas by the slurry in the probe.

2.4.2 Floating Bed Absorber

The floating bed absorber (hereafter referred to as the FBA) includes a sump, two contact stages, and a liquid disengagement section. The FBA is depicted in Figures 2.5 and 2.6. This countercurrent device admits the flue gas through the sump. Ancillary components of the FBA sump include the following: a liquid level controller, sump observation window, and level indicator.

Above the sump the FBA consists of two stages. Each tray has an effective flow area of 2 square feet and consists of a 1/8-inch thick stainless steel plate perforated with 3/8-inch-diameter holes on staggered 1/2-inch centers. Each stage is packed with 6 to 8 inches of "wiffle balls."

The spray nozzle located above the top tray directs the spray of absorbing slurry onto the top tray. Since the gas rises countercurrent through the slurry, it comes into intimate contact with the absorbing slurry. Gas leaving the top tray flows through an angle iron baffle section which serves to trap large water drops, then through a York Demister to ensure that all remaining droplets are removed. The Demister is located at the very top of the FBA and consists of about 6 inches of Teflon mesh fibers. See Figure 2.7.

Flow to the spray nozzle is controlled by the aforementioned pinch valve arrangement, and the slurry composition in the sump is controlled by the product flow rate and MgO makeup rates.

2.5 INDUCED DRAFT FAN SECTION

The cleansed flue gas leaving the FBA passes downward through a vertical length containing an orifice meter, a gas sampling probe, and a particulate sampling port with slide valve. The vertical duct ends at a blank flange. Approximately 3 feet up from the flange is the takeoff for the induced draft fan. The purpose of this length of pipe is to trap any large liquid or solid particles before the gas enters the I.D. fan. A pneumatically operated damper was located at the fan inlet.

2.6 NO_X SCRUBBER AND COMPONENTS

2.6.1 NO_2 Injection System

The flue gas leaving the I.D. fan contained only small concentrations of fly ash and SO_2. However, the nitric oxide concentration (NO) was still at the same level as in the furnace exhaust gases. The flue gas left the I.D. fan through a horizontal 10-inch stainless steel (316) duct to the NO_X scrubber. At a distance of 6 feet from the I.D. fan, gaseous NO_2 was injected into the duct through a multi-orificed dispersion tube. The purpose behind the dispersion tube design was to disperse the gases as rapidly as possible to minimize the probability of extraneous reactions occurring with the momentarily concentrated NO_2 gas as it left the orifices of the dispersion tube. The NO_2 injection system is shown schematically in Figure 2.8 and consists of bottled liquid NO_2 provided with an eductor tube so that the NO_2 could be withdrawn as a liquid, a rotometer to monitor the liquid NO_2, a steam-heated boiler to vaporize the NO_2, and the dispersion tube. Located immediately after the dispersion tube, a

6-1/2-inch inside diameter orifice was placed for the dual purpose of monitoring the total flue gas flow and to act as a means for mixing the NO_2 with the flue gas prior to entry into the NO_X scrubber.

The boiling point for NO_2 is 70°F. Thus, the tendency to form gas bubbles in the line ahead of the rotometer was an operating problem. This problem was solved by packing the valve at the NO_2 bottle in ice thereby substantially subcooling the NO_2.

2.6.2 NO_X Scrubber

The NO_X scrubber was placed approximately 12 feet from the I.D. fan. A dimensional drawing of the scrubber is shown in Figure 2.9. The basic criteria for the design and location of this scrubber are as follows:

1. Provide maximum practical gas contact time.
2. Sufficient mass transfer surface area to maximize the probability that the system would be chemical reaction rate controlling.
3. Open gas flow path.
4. Locate sufficiently far from the NO_2 injection point to provide good mixing before entry into the scrubber.
5. Locate out-of-doors as a safety precaution.

The scrubber was designed for a total gas contact time of approximately two seconds. This is about three times the maximum gas contact time employed in the FBA. If the process still proves to be chemical reaction rate controlling, then it shall be deemed as being commercially unfeasible.

The mass transfer area consisted of parallel fiber glass window screens which were irrigated with MgO slurry by four Spraying Systems 2H560WSQ stainless steel square-pattern spray nozzles. A screen material was selected because of its superior wetting characteristics. The parallel arrangement provides for an open free flow path for the gas.

Locating the scrubber out-of-doors helped insure that no personnel in the test building would inadvertently be exposed to noxious levels of NO_2 which might leak from the slightly pressurized scrubber. Views of the scrubber, both internal and overall are shown in Figures 2.10 and 2.11.

2.7 OVERALL PILOT PLANT SCHEMATIC

Figure 2.12 shows in schematic form the overall arrangement and the approximate nominal flow rates of the various streams.

TABLE 2.1. FUEL ANALYSIS

PULVERIZED COAL ANALYSES

Lab. Serial No.	C-13425	C-13426	C-13427
Sample Description	Coal from BCTU Hopper 3-9-70 2200 hrs.	Coal from BCTU Hopper 3-10-70 1000 hrs.	Coal
Ash (Dry) %	9.6	9.2	--
Sulphur (Dry) %	3.8	4.1	4.5
Carbon (Ult.)%	--	--	--

Lab. Serial No.	C-13260	C-13386	C-13377
Sample Description	Pulv. Coal Sample N. Industry Strip	Pulverized Coal Ohio Seam #5&6	Pulverized Coal Ohio Seam #5&6
Total Moisture, %	3.0	4.2	
Ash, %	8.1	--	7.4
Sulphur, %	4.1	3.8	3.7
Btu per lb. (Dry)	12730	12700	
Btu per lb. (M&A Free)	13850		

NATURAL GAS ANALYSES

Sulphur Compounds	
Hydrogen Sulfide, gr/100 cf	0.017
H_2S Sulphur Equiv., gr/100 cf	0.018
Mercaptans - S - Equiv.	0.007
Sulfide Sulphur, gr/100 cf	0.007
Residual Sulphur, gr/100 cf	0.004
Total Sulphur, gr/100 cf	0.034

	Tennessee Guernsey
Date of Sample	2/12/69
Components:	Mol %
Nitrogen	0.44
Carbon Dioxide	0.65
Methane	95.40
Ethane	2.86
Propane	0.49
Iso-Butane	0.07
N-Butane	0.06
Iso-Pentane	0.02
N-Pentane	0.01
Total	100.00

FIGURE 2.1. MAGNESIA BASE SLURRY SCRUBBING PILOT PLANT

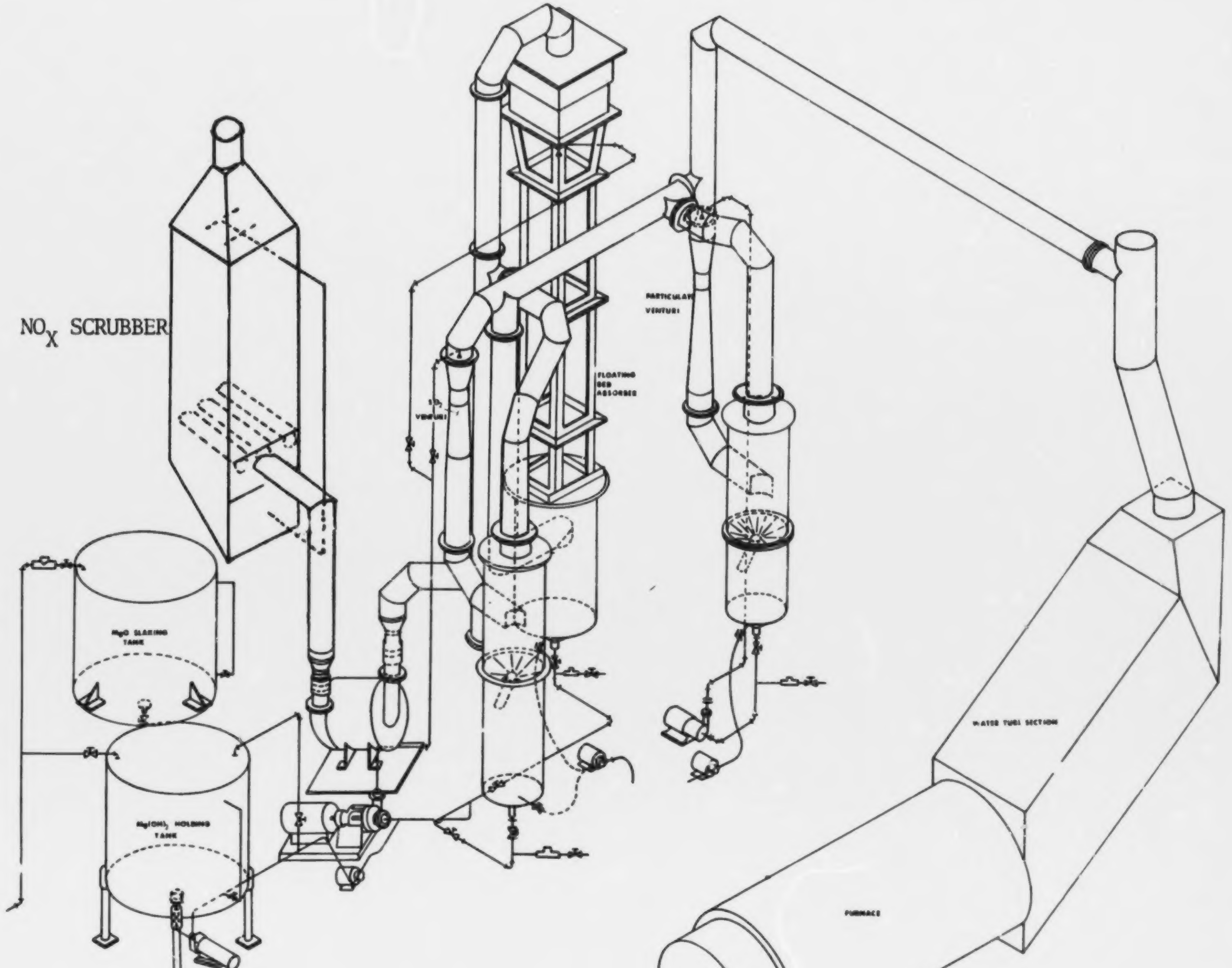

NO_X SCRUBBER
PARTICULATE VENTURI
FLOATING BED ABSORBER
SO_2 VENTURI
MgO SLAKING TANK
$Mg(OH)_2$ HOLDING TANK
WATER TUBE SECTION
FURNACE
PULVERIZED COAL

FIGURE 2.2. BASIC COMBUSTION TEST FURNACE

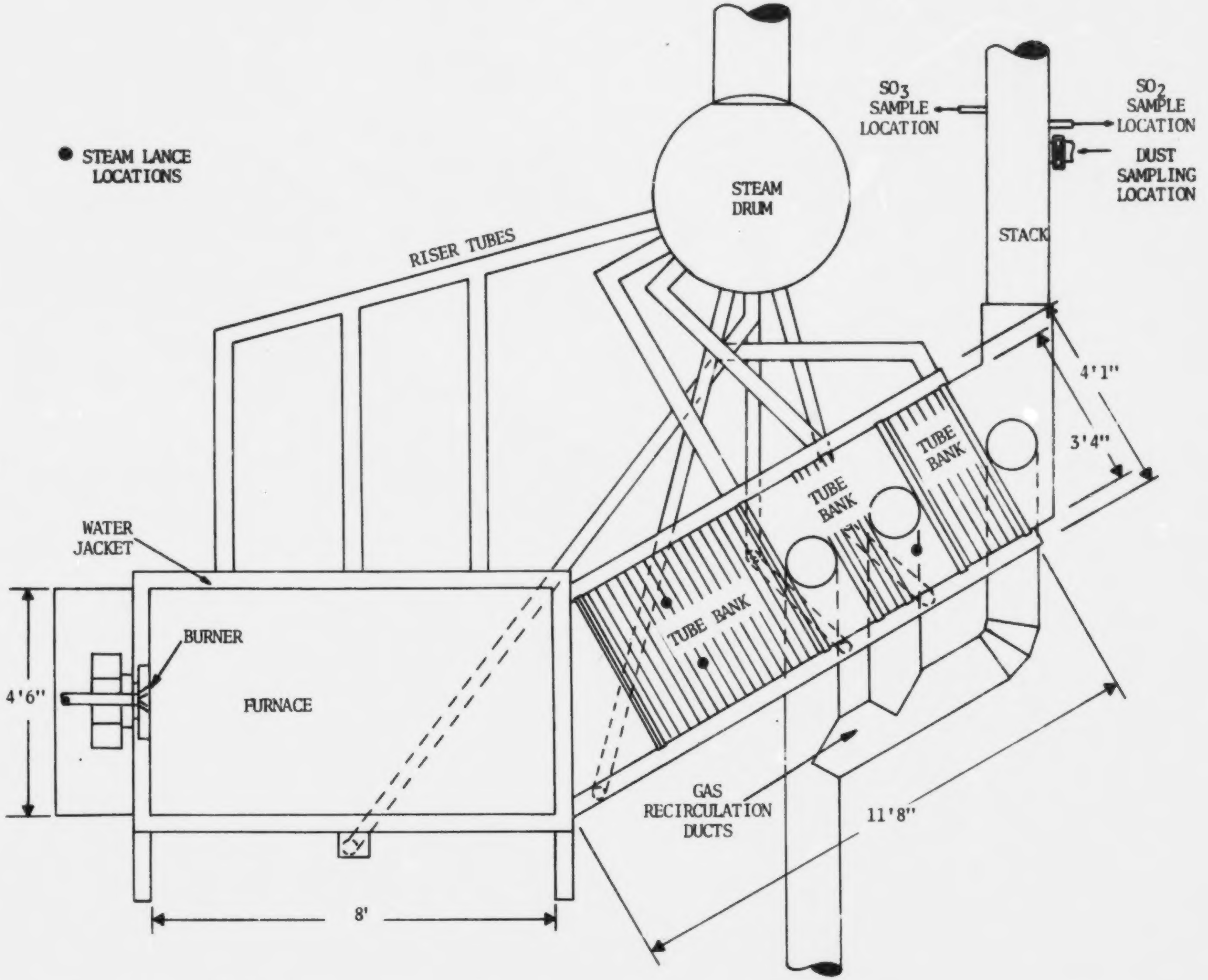

● STEAM LANCE LOCATIONS
STEAM DRUM
RISER TUBES
SO_3 SAMPLE LOCATION
SO_2 SAMPLE LOCATION
DUST SAMPLING LOCATION
STACK
4'1"
3'4"
TUBE BANK
TUBE BANK
TUBE BANK
WATER JACKET
BURNER
FURNACE
4'6"
GAS RECIRCULATION DUCTS
11'8"
8'

FIGURE 2.3. PARTICULATE SCRUBBING SYSTEM

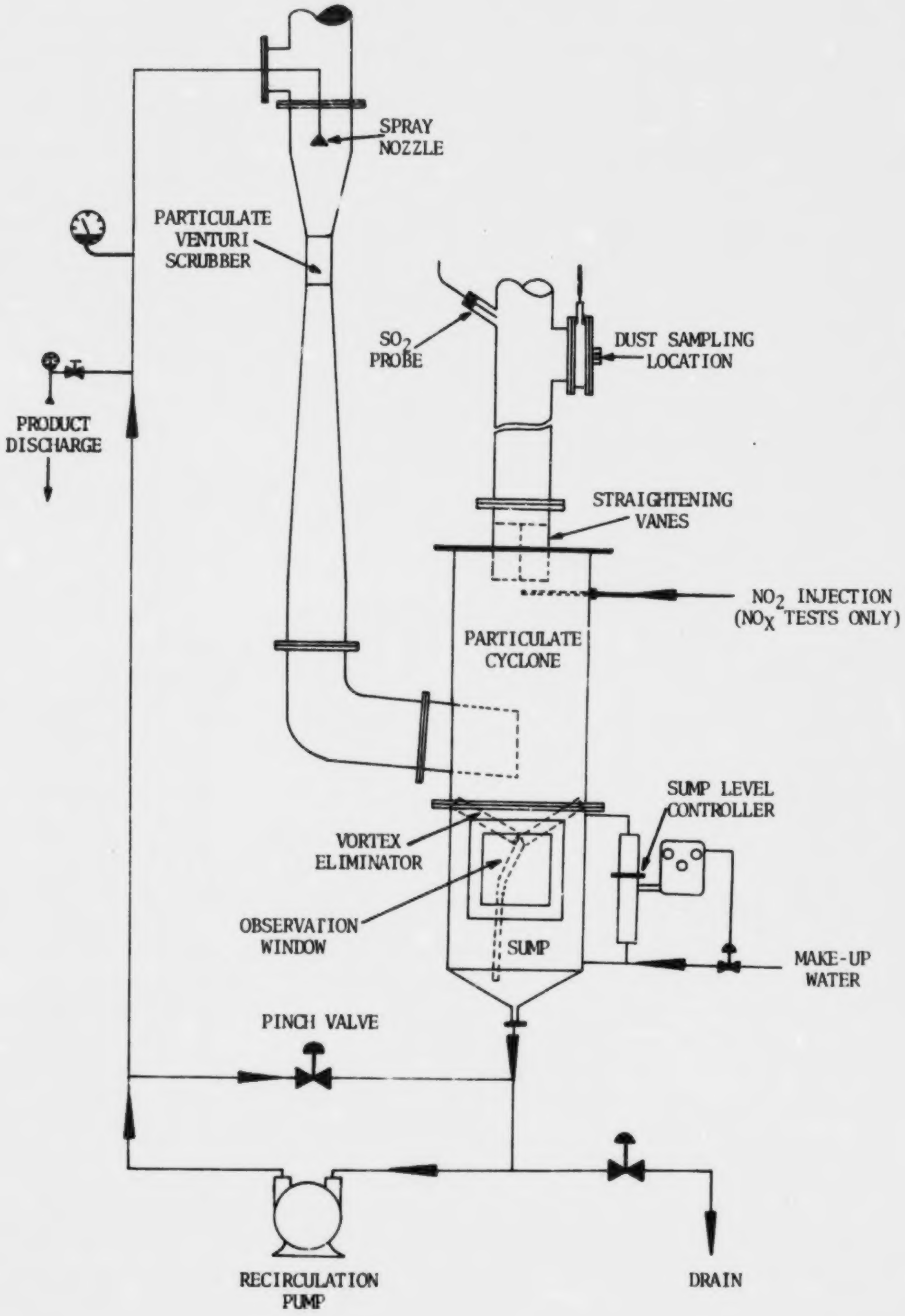

SPRAY NOZZLE
PARTICULATE VENTURI SCRUBBER
SO_2 PROBE
DUST SAMPLING LOCATION
PRODUCT DISCHARGE
STRAIGHTENING VANES
NO_2 INJECTION (NO_X TESTS ONLY)
PARTICULATE CYCLONE
SUMP LEVEL CONTROLLER
VORTEX ELIMINATOR
OBSERVATION WINDOW
SUMP
MAKE-UP WATER
PINCH VALVE
RECIRCULATION PUMP
DRAIN

FIGURE 2.4. PARTICULATE SCRUBBING SYSTEM

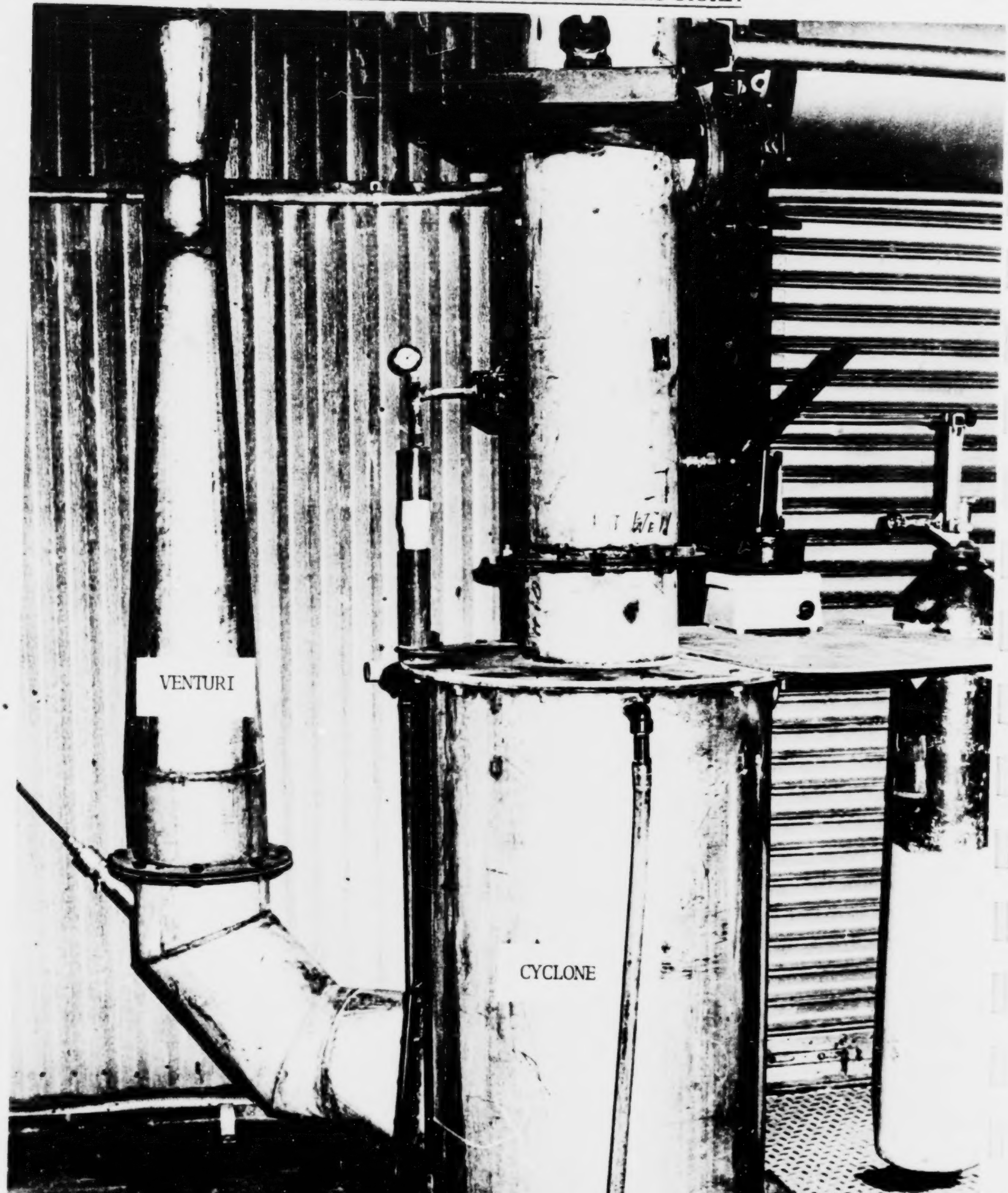

VENTURI
CYCLONE

FIGURE 2.5. FLOATING BED ABSORBER

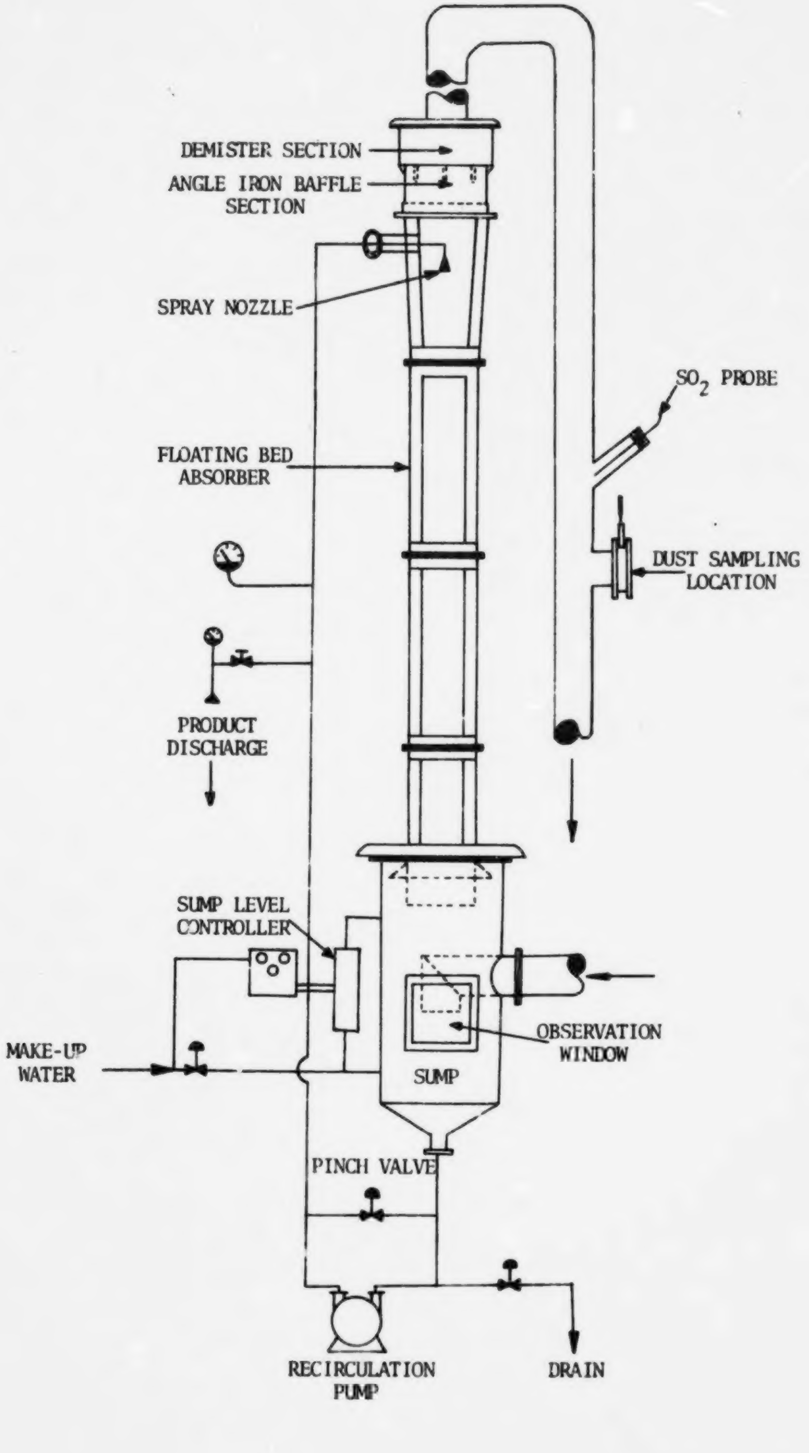

DEMISTER SECTION
ANGLE IRON BAFFLE SECTION
SPRAY NOZZLE
SO_2 PROBE
FLOATING BED ABSORBER
DUST SAMPLING LOCATION
PRODUCT DISCHARGE
SUMP LEVEL CONTROLLER
OBSERVATION WINDOW
MAKE-UP WATER
SUMP
PINCH VALVE
RECIRCULATION PUMP
DRAIN

FIGURE 2.6. FLOATING BED ABSORBER

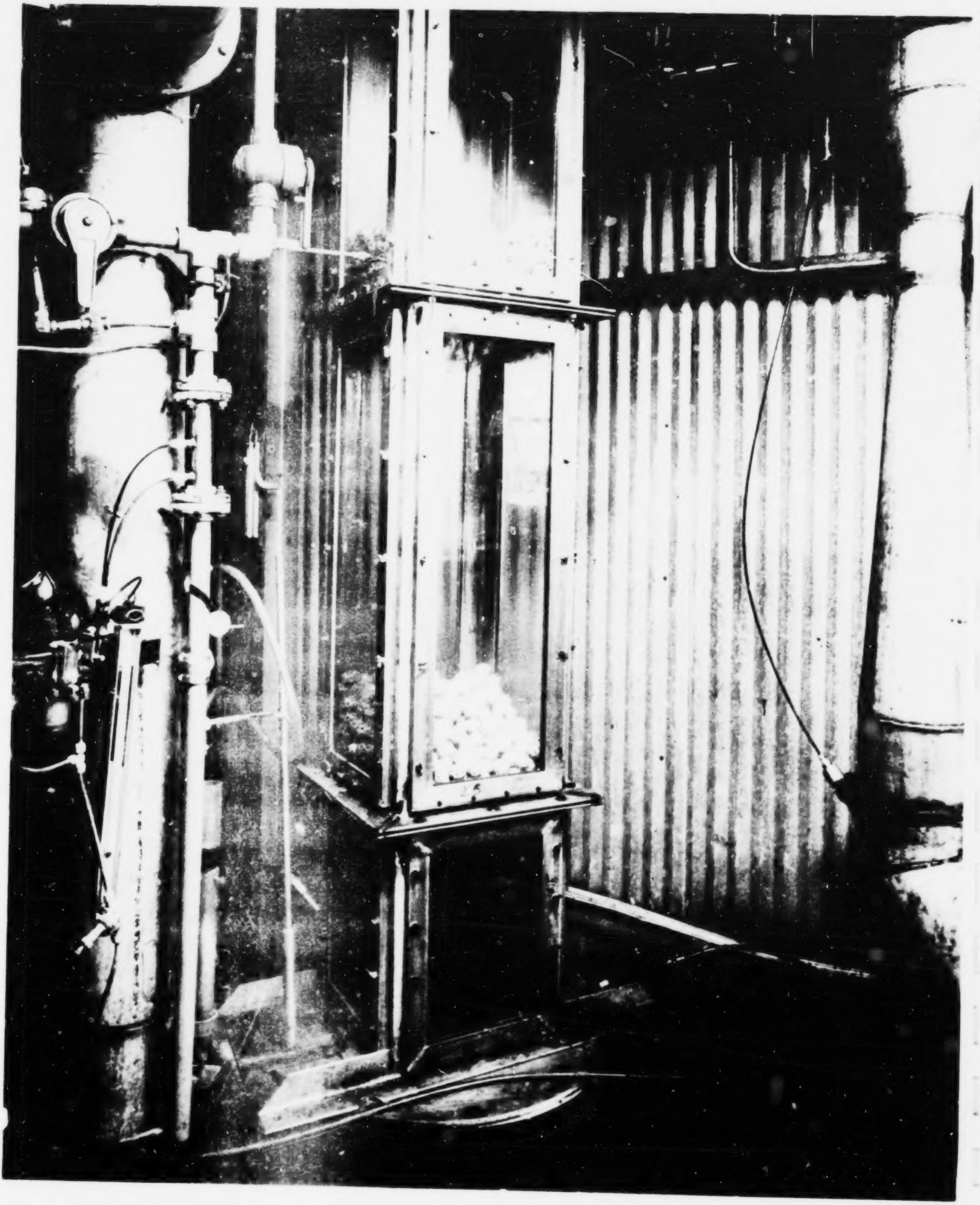


FIGURE 2.7. SLURRY ENTRAINMENT SEPARATOR SECTION

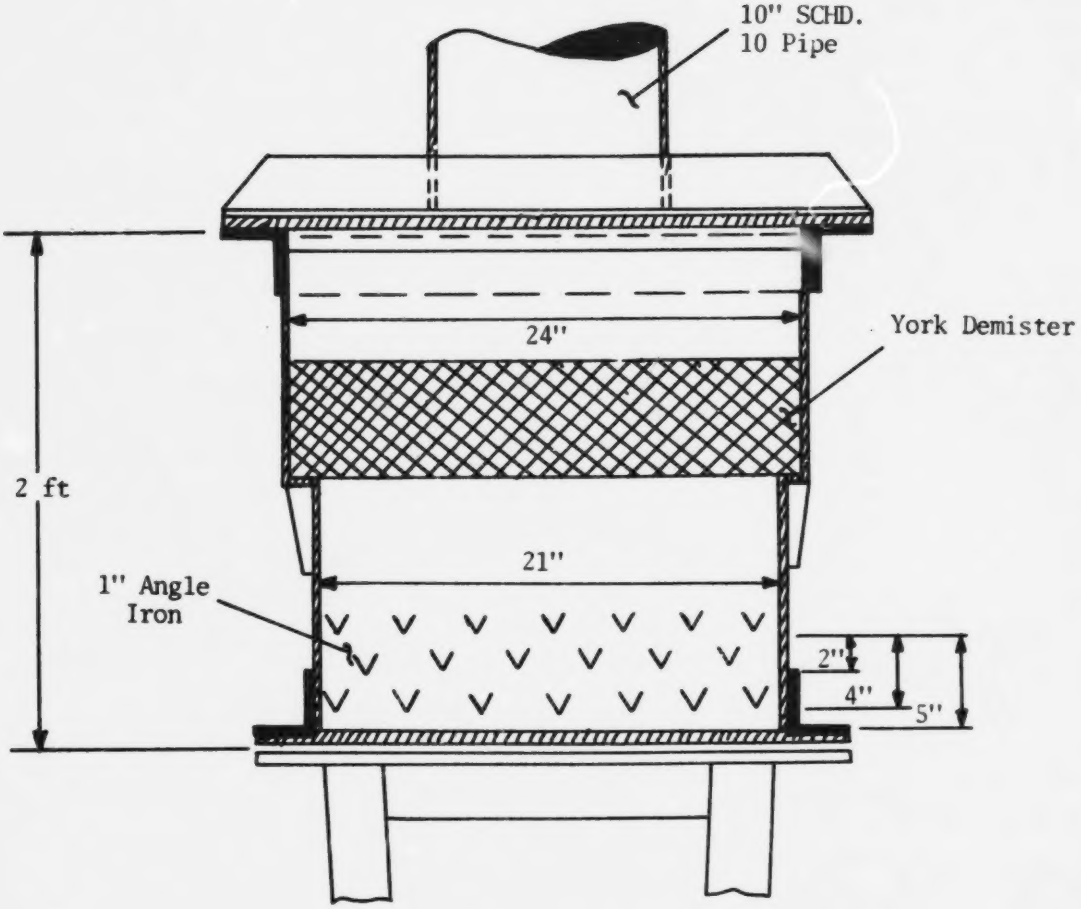

10" SCHD.
10 Pipe
York Demister
24"
2 ft
21"
1" Angle
Iron
2"
4"
5"

FIGURE 2.8. NO_2 INJECTION SYSTEM

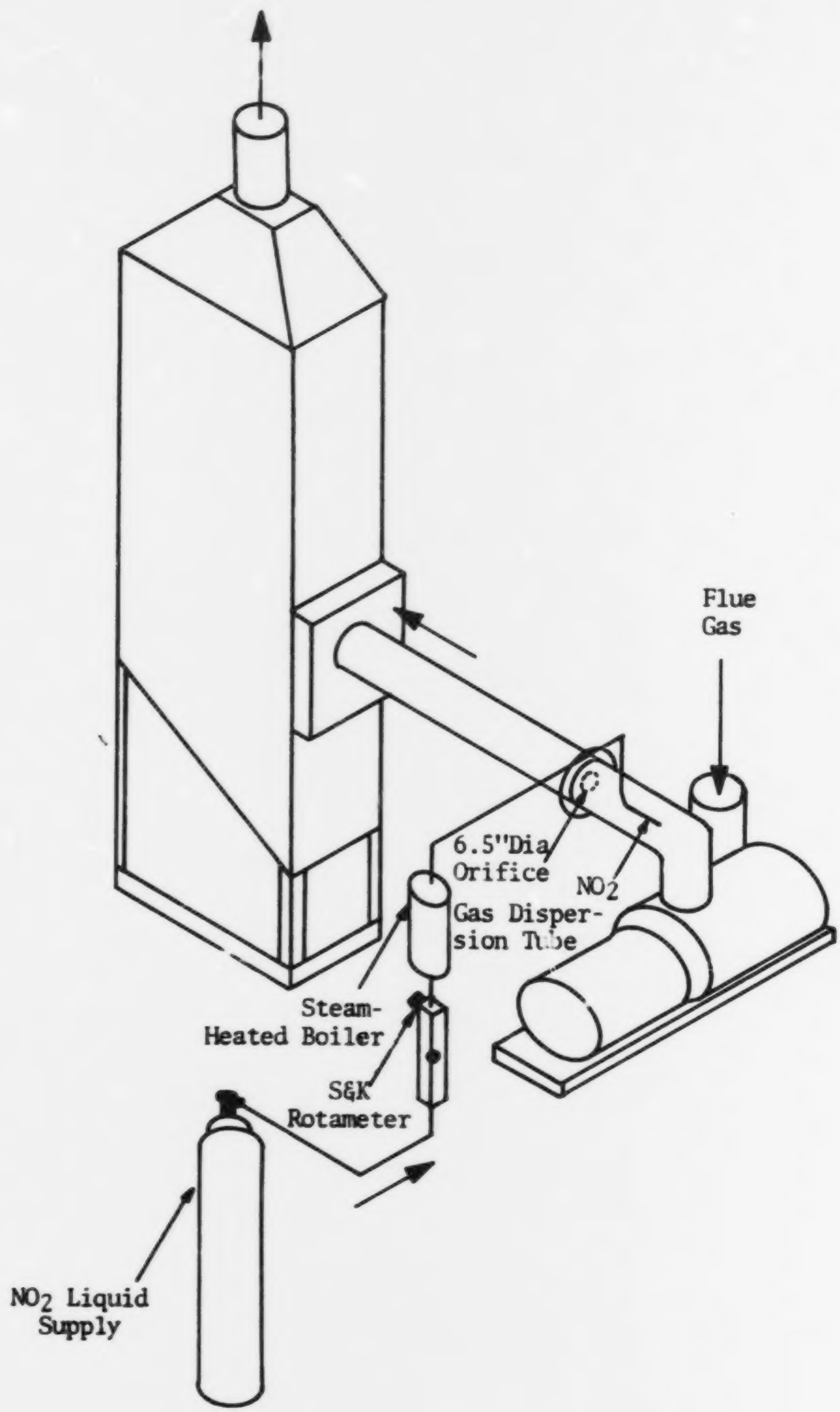

Flue Gas
6.5"Dia Orifice
NO_2
Gas Dispersion Tube
Steam-Heated Boiler
S&K Rotameter
NO_2 Liquid Supply

FIGURE 2.9. NO_X SCRUBBER DIMENSIONS

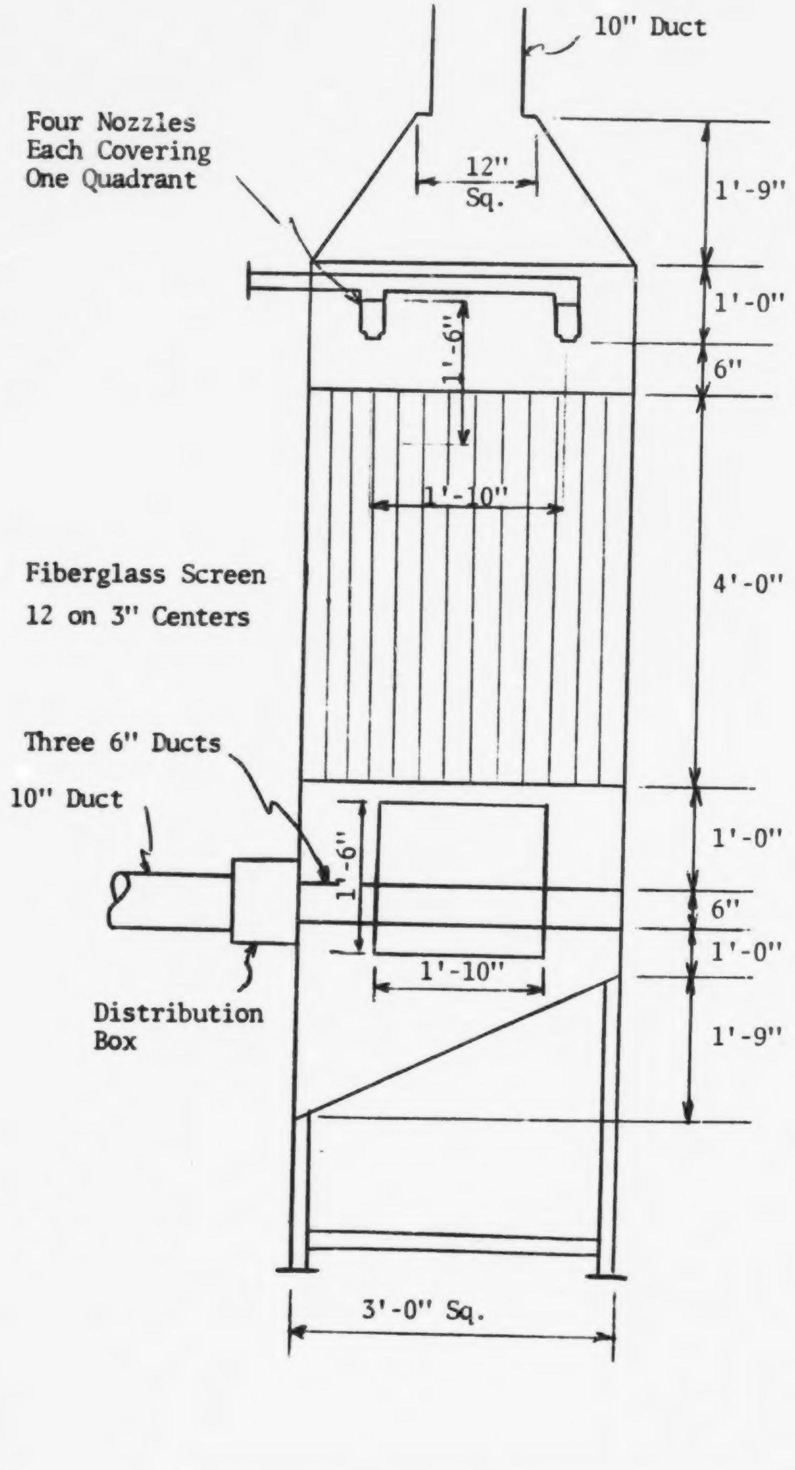

10" Duct
Four Nozzles
Each Covering
One Quadrant
12"
Sq.
1'-9"
1'-0"
1'-6"
6"
1'-10"
Fiberglass Screen
12 on 3" Centers
4'-0"
Three 6" Ducts
10" Duct
1'-6"
1'-0"
6"
1'-0"
1'-10"
Distribution
Box
1'-9"
3'-0" Sq.

FIGURE 2.10. NO$_X$ SCRUBBER

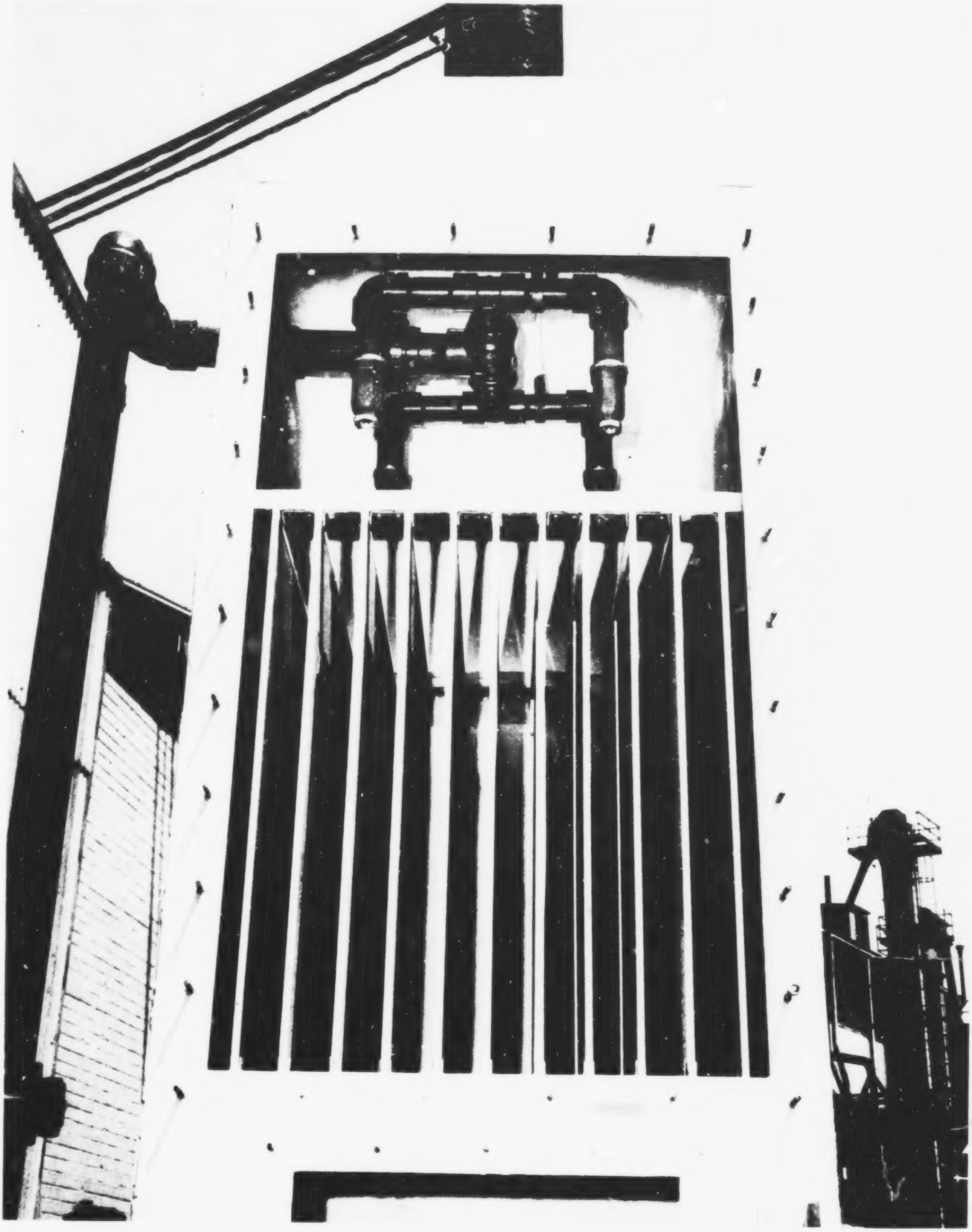


FIGURE 2.11. NO_X SCRUBBER AND LEACH BED

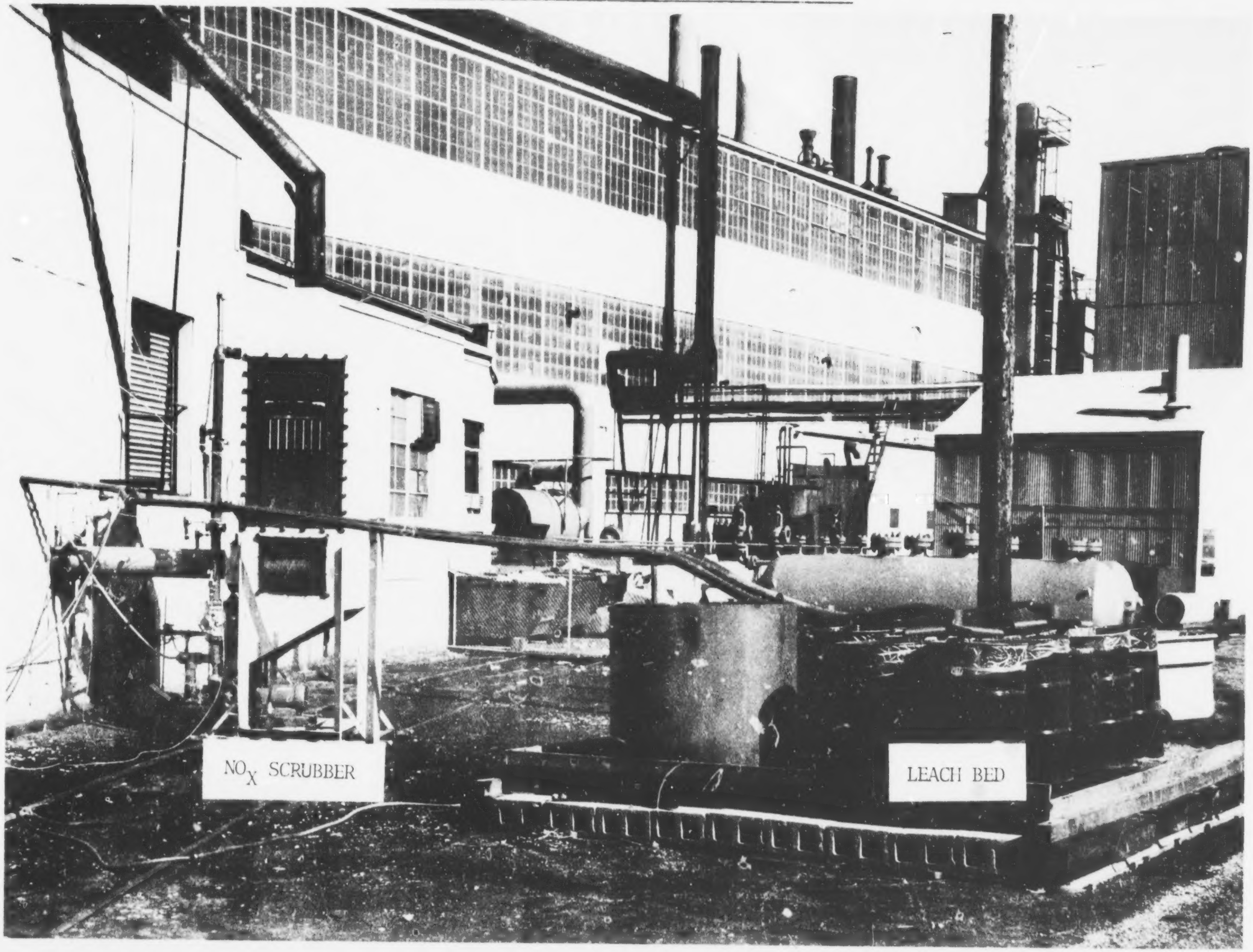
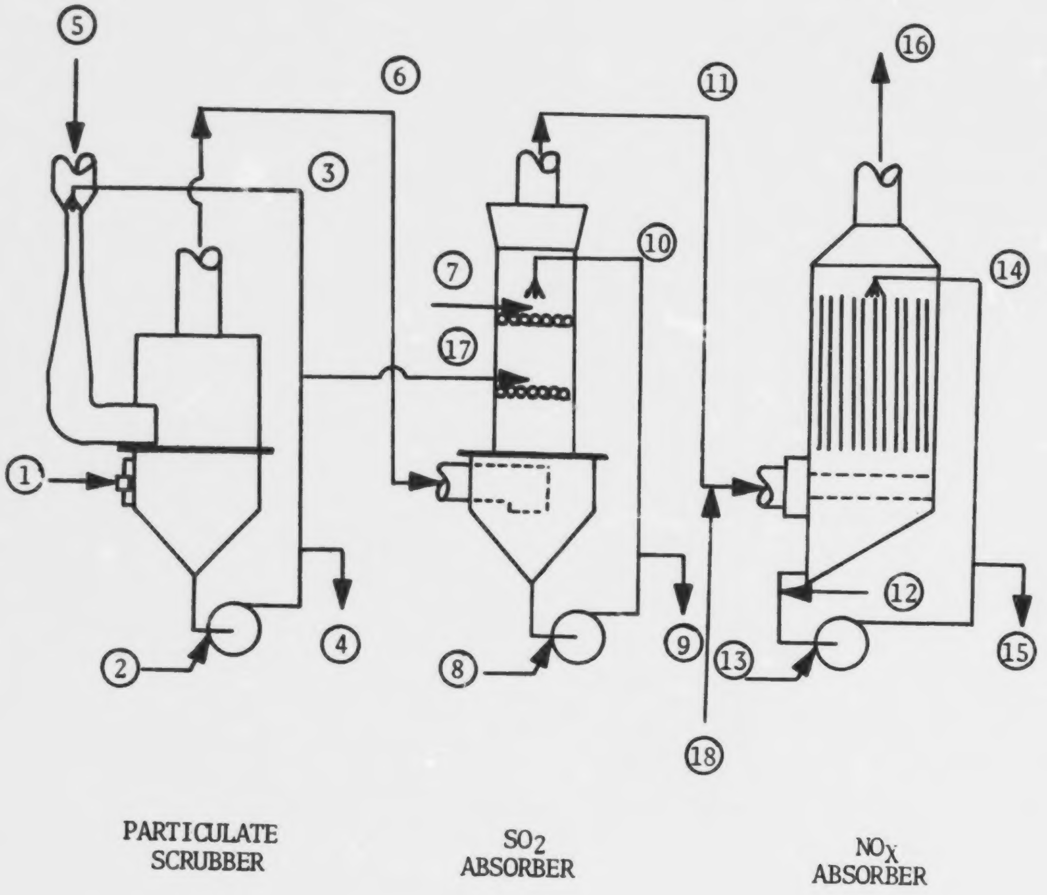

NO_X SCRUBBER
LEACH BED

FIGURE 2.12. PILOT PLANT FLOW SCHEMATIC



5
6
3
11
16
10
7
17
14
1
12
2
4
8
9
13
15
18
PARTICULATE SCRUBBER
SO_2 ABSORBER
NO_X ABSORBER

	Stream	Nominal Flow Rates lb/hr		Stream	Nominal Flow Rates lb/hr
1	Makeup Water	750	10	Recirculated Spray	22,200
2	Seal Water	120	11	Flue Gas	4,600
3	Recirculated Spray	11,500	12	Makeup MgO	196
4	Product Fly Ash Slurry	540	13	Seal Water	120
5	Flue Gas	4,400	14	Recirculated Spray	76,500
6	Flue Gas	4,600	15	Product Slurry	327
7	Makeup MgO Slurry	286	16	Flue Gas	4,600
8	Seal Water	120	17	Fly Ash Slurry Bleed	60
9	Product Slurry	498	18	NO_2 Injection	2.1

3.0 TEST APPARATUS AND PROCEDURES

3.1 PLANT OPERATING TEST PROCEDURE

A day's testing began with the startup of the furnace. First, the air heaters were fired and allowed to reach temperature (∿750°F). This usually took an hour. The coal feed was then ignited. The furnace gases at this time were vented directly to the atmosphere via the stack relief. A waiting period of approximately 1 to 2 hours followed until the furnace ignition was stable.

While waiting for the desired furnace conditions, the particulate scrubbing system and the FBA were being readied for operation. During this time the MgO makeup slurry was prepared to the proper concentration. When the furnace was ready, the relief valve was closed, thereby directing the flue gas to the scrubbing systems.

After the transfer of gas was made, it usually took an hour after the MgO makeup was started before the chemical composition of the FBA reached steady-state. Steady-state was assumed when two or three Palmrose analyses taken at 10-minute intervals showed that the system had reached the desired operating conditions and also when the SO_2 concentration at the pilot plant exit was constant and less than 50 ppm.

The NO_2 scrubber was started by filling the sump with MgO slurry and recirculating the slurry. During the startup period no slurry was added nor withdrawn. The NO_2 flow was set as soon as the NO concentration was known. The liquid level was maintained at as low a level as was consistent with good pump operation. This insured a more rapid approach towards steady-state. It took at least one hour to reach steady-state in the NO_X scrubber. A typical test lasted for about an hour, during which a complete set of data was taken.

During a test several samples were taken and put into storage in the event that they were needed at a later date. If certain data were found to be unusual, an analysis of the stored samples could provide a means for determining what occurred. Samples collected and stored in 8-ounce bottles consisted of the following: MgO makeup slurry, particulate cyclone slurry, FBA slurry, NO_X scrubber slurry, and a makeup water sample.

After a test was completed, the operating conditions were changed for the next test. Depending upon the operating parameter changed, there was usually a waiting period of about 1/2 to 1 hour before steady-state was again reached and the next test could begin.

3.2 FLUE GAS ANALYSIS

3.2.1 General Analysis

The method employed for SO_2 analysis was primarily the Barton coulometric titrator as previously described.(3) The sampling arrangement is shown in Figure 3.1. At the beginning of these tests a second approach for SO_2 analysis was attempted. This involved the use of a DuPont 460 SO_2/NO_2 Analyzer. This UV analyzer has been used successfully on in-plant experiments on a particulate free synthetic flue gas. However, during this test the DuPont continuously registered SO_2 concentration 150 to 250 ppm higher than the Barton. The discrepancy was investigated by measuring the SO_2 concentration with the Reich iodine titration method.(4) The Reich method was found to agree with the Barton titrator. The possibility that particulate matter was causing an SO_2 interference on the DuPont 460 was then explored analytically. It was deducted that flue gas containing 0.015 grains/DSCF and a $\bar{D}_{32}$ of 0.25 micron could produce the observed discrepancy. These values are certainly within the range of possibility. Thus, the DuPont was dropped as an SO_2 monitor.

Fly ash and SO_3 concentrations were not measured during this test program.

3.2.2 NO_X Analysis

It is generally recognized that the measurement of the oxides of nitrogen is a difficult task. The circumstance here was even more so since the split between nitric oxide (NO) and nitrogen dioxide (NO_2) was required. To accomplish this the following methods were specified:

1. Phenoldisulfonic acid (PDS) for NO + NO_2.
2. Saltzman for NO_2 only.
3. Dynasciences "Fuel Cell" for NO only.

It became evident, however, that neither of the latter two methods were selective. The result of this situation was, therefore, to obscure the analysis of the data. The application of these methods are described below.

The PDS method was the primary means employed for determining overall performance.

PDS analyses were taken at three points: the FBA exit, the NO_x scrubber inlet, and the NO_x scrubber exit. Figure 3.2 depicts the sampling locations for all three locations.

A typical PDS sampling and analysis consists of the following. To a 1000 ml flask is added an absorbing solution consisting of hydrogen peroxide and dilute sulfuric acid. The flask is then evacuated; a gas sample is now ready to be taken. The line to the other analyzers is pinched off, and one arm of the three-way stopcock is connected to the tee. The stopcock is opened, and the gas sample is drawn into the flask.

The nitrogen oxides are converted to nitric acid by the absorbent solution and are then reacted with phenoldisulfonic acid to produce a yellow compound, which is measured colorimetrically. The color is measured with a photometer and compared with calibration curves made with a solution containing a known amount of nitrate.

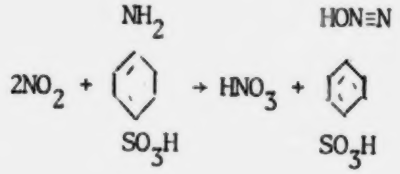
A more complete and descriptive explanation of the phenoldisulfonic acid method used in these tests is given in the American Society for Testing and Materials, Standard Method of Test for OXIDES OF NITROGEN IN GASEOUS COMBUSTION PRODUCTS (PHENOL-DISULFONIC ACID PROCEDURE), ASTM Designation: D1608-60. With the exception of the following modifications, the ASTM Method was followed as written:

Modifications to ASTM Method:

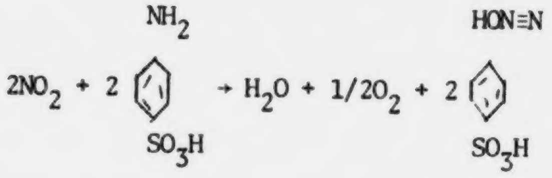
1. Absorbent Solution - 2 ml of H_2O_2 (3%) was added to 50 ml of 0.1N H_2SO_4. This is about four times the peroxide concentration called for in the ASTM Standard.
2. In place of 1N sodium hydroxide solution, 1N potassium hydroxide solution was used.

The Saltzman method of analysis employed for these tests is a modification by Strom(5) which permits the use of the Saltzman method for high concentrations of NO_2. A detailed description of the method is attached in Appendix A. The intent of the Saltzman method was to analyze for NO_2 only in the flue gas. However, it became evident during the tests that both NO and NO_2 were being analyzed. This observation was made in spite of the fact that Saltzman points to the observation that NO does not interfere substantially with the analysis. However, he did not perform his analysis with an $NO\text{-}NO_2\text{-}N_2$ gas mixture but rather with an $NO\text{-}N_2$ mixture.

The Saltzman analysis for samples containing only NO_2 depends upon the following two reactions proceeding at approximately the same rate:



$$2NO_2 + C_6H_4(NH_2)(SO_3H) \rightarrow HNO_3 + C_6H_4(N{\equiv}NOH)(SO_3H) \qquad (3\text{-}1)$$



$$2NO_2 + 2\,C_6H_4(NH_2)(SO_3H) \rightarrow H_2O + 1/2O_2 + 2\,C_6H_4(N{\equiv}NOH)(SO_3H) \qquad (3\text{-}2)$$

where the aromatic on the left is sulfonilic acid and the aromatic on the right is the diazosulfonilic acid.

If the disproportionating reaction (3-1) was much faster than the oxidation reaction (3-2), then one mole of NO_2 would produce only one half the color as one mole of sodium nitrite. If the reverse were true; i.e., if reaction (3-2) was faster, then one mole of NO_2 would develop the same color as one mole of $NaNO_2$. As Saltzman reports, however, both reactions are significant and one mole of NO_2 yields only as much color as 0.73 moles $NaNO_2$.

Now in the present system with mixtures of NO and NO_2, a third reaction is possible which makes it quite difficult to determine the sodium nitrite equivalency for the mixture; namely,

$$NO + NO_2 \rightarrow N_2O_3 \xrightarrow{H_2O} 2HNO_2 \qquad (3\text{-}3)$$

Both nitrous acid anhydride (N_2O_3) and nitrous acid (HNO_3) are at the same oxidation state. The extent to which reaction (3-3) takes place will affect that equivalence between NO_X ($NO + NO_2$) and the sodium nitrite. For instance, if equimolar quantities of NO and NO_2 were present in the sample when taken and if reaction (3-3) predominated, then the NO_X-$NaNO_2$ equivalence would, of course, be unity. Since reaction (3-3) is a gas-phase reaction while reactions (3-1) and (3-2) are aqueous reactions, it is quite possible that reaction (3-3) does indeed predominate. Table 3.1 summarizes the expected sodium nitrite equivalence for various ratios of NO_2/NO assuming reaction (3-3) is far faster than the other two reactions. For example, if 15 minutes elapsed between the time that a sample containing 600 ppm NO is drawn and the time that the sample is analyzed, 84% of the original NO can be oxidized to NO_2. See Figure 3.3.

It is apparent from Table 3.1 that unless some aleternate means is available to determine the NO_2/NO ratio, the correct equivalence, C_{eq}, cannot be assigned. There are fortunately means available by which the ratio can at times be estimated as will be shown later.

Finally, since the gas sample is injected into the septum bottle, which is filled with air, significant oxidation of the NO can take place by the time the sample was analyzed.

The Dynasciences NX-130 monitor was employed with the hope of being able to monitor only NO from the NO_X mixture. Refer to Figure 3.2 for a description of the sampling arrangement. Although this monitor is designed to measure both NO and NO_2, it was hoped that by passing the flue gas through Mallcosorb the NO_2 could be quantitatively removed. As was evident from the tests, this was not the case. Specifically, when monitoring flue gas at the FBA exit and the NO_X scrubber inlet with NO_2 being injected in between, the apparent NO_X concentration increased substantially. With a bias voltage of 0.4 volts across the fuel cell, the relationship between monitor response and gas composition is as follows:

$$y'_{NO_X} = y_{NO} + 0.53\ y_{NO_2}$$

where y'_{NO_X} = apparent NO_X concentration, ppm by volume
y_{NO} = NO concentration, ppm by volume
y_{NO_2} = NO_2 concentration, ppm by volume

Thus, unless the ratio of NO to NO_2 is known the NX-130 monitor output is difficult to translate. It is known, however, from combustion kinetics that the NO_X split at the furnace exit is essentially all NO. However, given sufficient time and oxygen within the flue gas, the NO will partially oxidize to NO_2. Likewise as NO_2 forms it can further react with NO to form N_2O_3 and/or HNO_2, the latter constituent very likely being removed in the Mallcosorb.

To investigate the above question the following analysis is presented. Since the N_2O_3 formation is probably much faster than the NO oxidation, an equilibrium conversion of N_2O_3 (HNO_2) can probably be assumed. It would follow then that if we started with 600 ppm NO (at furnace exit) and assumed also that the flue gas contains 3% oxygen, then by the time the flue gas passed to the FBA exit sampling point and through the sample line to the Mallcosorb at the NX-130 monitor, a period of ∿ 60 seconds, ∿ 20 ppm NO_2 could have formed (see Figure 3.4). At 80°F about 16 ppm HNO_2 could also have formed (see Figure 3.5). The HNO_2 would most likely be removed in the Mallcosorb. Thus, the NX-130 would have registered as follows:

$$y'_{NO_X} = (600 - 20) + (0.53)(21 - 16/2) = 587 \text{ ppm}$$

This is an error of only 2%. However, when the NX-130 is monitoring the NO, NO_2, H_2O mixture at the NO_X scrubber inlet and exit, the potential for erroneous answers is substantially increased. For instance, assume the following typical condition:

$[NO]$ = 600 ppm

$[NO_2]$ = 600 ppm

$[H_2O]$ = 15.1% at 130°F

≈ 6.5% at 100°F

TEMP. BULK GAS = 130°F

TEMP. SAMPLED GAS = 100°F

From Figure 3.5 the equilibrating HNO_2 is 106 ppm and 148 ppm at 100°F and 130°F respectively. Since the HNO_2 will be absorbed into the Mallcosorb at 100°F, the apparent NO_X on the NX-130 will be:

$$NO_X' = (600 - 106/2) + (0.53)(600 - 106/2) = 573.5 + 303.5 = 837 \text{ ppm}$$

This amounts to an error of 30%.

The net result of the discussion presented above is that because of several NO_X measuring problems, a significant uncertainty exists in all the NO_X values with the possible exception of the PDS method. That is, there is no interpretive problems with the PDS method except for its usual characteristic scatter.

In summary, the NO_X analyses will be interpreted in this report as follows:

1. PDS: Standard Procedure.
2. Saltzman: The nitrite equivalence (C_{eq}) will be assumed to equal 1.0.
3. Dynasciences NX-130: Valid only on NO_2 free samples.

3.3 LIQUID ANALYZER

The sulfite, MgO, and suspended solids analysis procedures performed on all three process streams were identical to those used during the previous work.(6) No sulfate analyses were performed on the FBA product. However, sulfate, nitrite, and nitrate analyses were all performed upon the NO_X scrubber recirculated slurry. The sulfate analysis used was the standard gravimetric analysis of precipitated barium sulfate. The nitrite analysis was the ASTM method D-1254-67. Finally, the Brucine Alkaloid Method was used for the nitrate analysis.

TABLE 3.1. SODIUM NITRITE EQUIVALENCE FOR MIXTURES OF NO AND NO_2

NO_2/NO	C_{eq}
> 1.0 (excess NO)	1.0 (excess NO will be missed)
1.0	1.0
1.2	0.975
1.4	0.955
∞ (no NO)	0.73

FIGURE 3.1. SO_2 SAMPLING SYSTEM

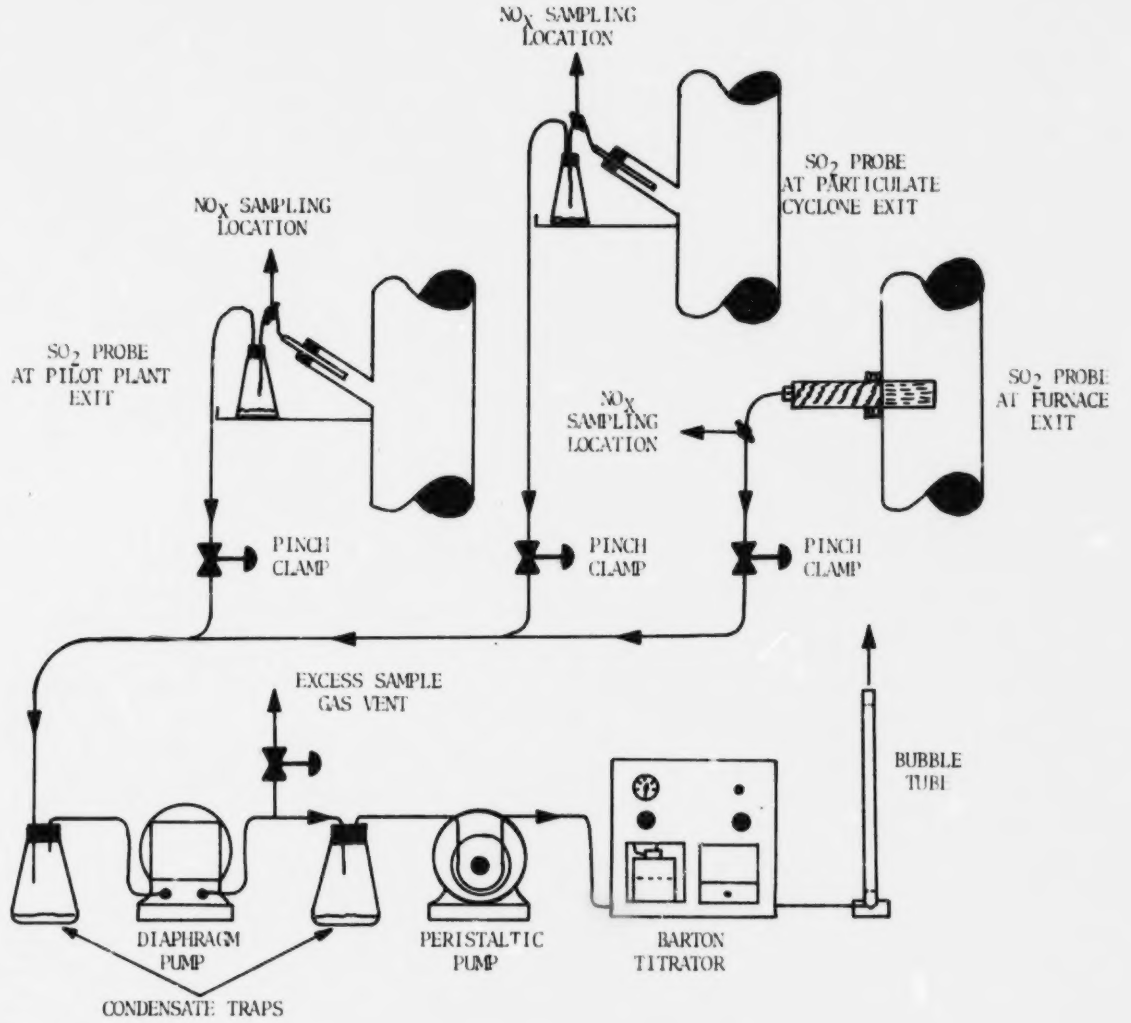

NO_X SAMPLING LOCATION
NO_X SAMPLING LOCATION
SO_2 PROBE AT PARTICULATE CYCLONE EXIT
SO_2 PROBE AT PILOT PLANT EXIT
NO_X SAMPLING LOCATION
SO_2 PROBE AT FURNACE EXIT
PINCH CLAMP
PINCH CLAMP
PINCH CLAMP
EXCESS SAMPLE GAS VENT
BUBBLE TUBE
DIAPHRAGM PUMP
PERISTALTIC PUMP
BARTON TITRATOR
CONDENSATE TRAPS

FIGURE 3.2. NO$_X$ SAMPLING SYSTEM

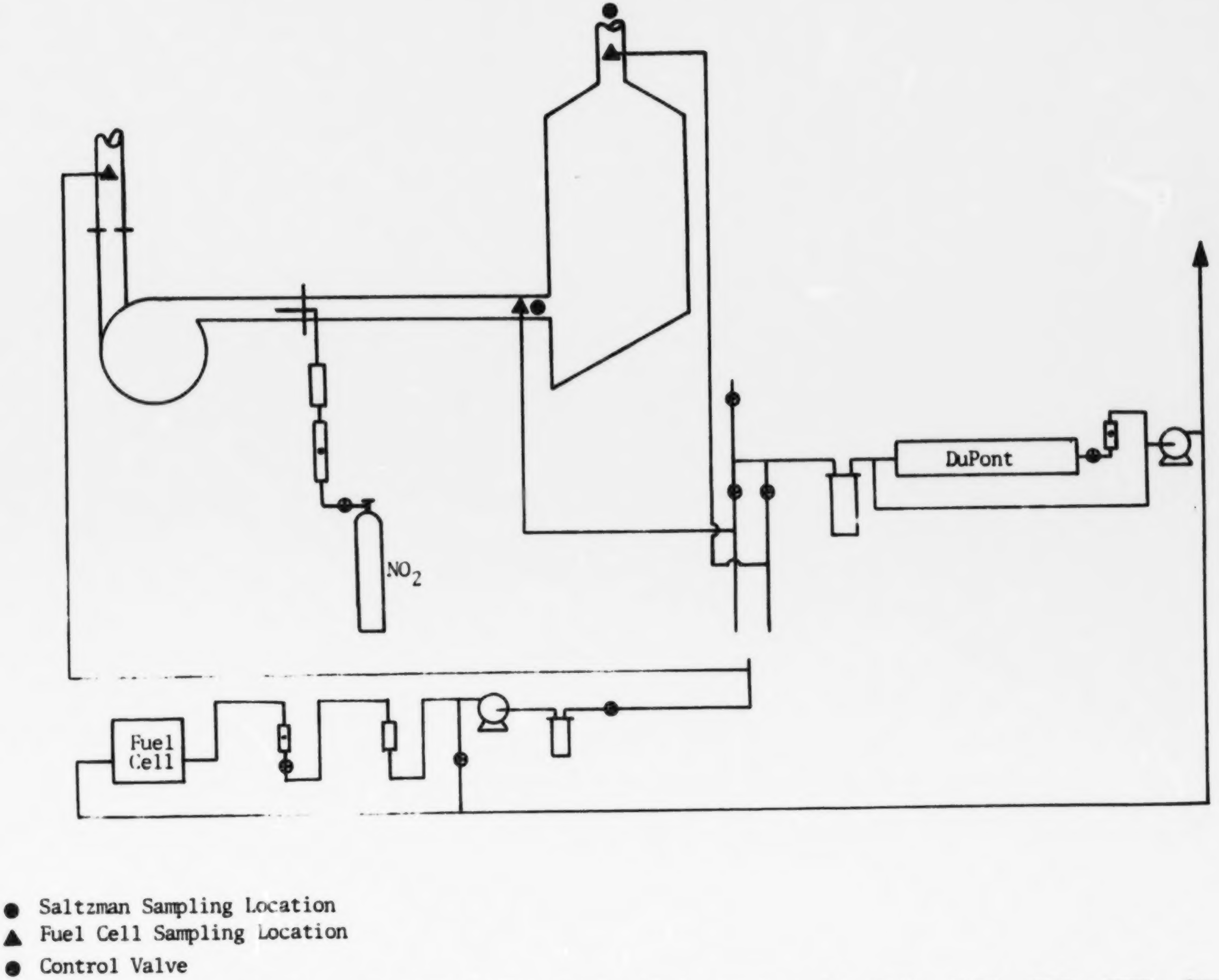

NO$_2$
DuPont
Fuel Cell
● Saltzman Sampling Location
▲ Fuel Cell Sampling Location
● Control Valve

FIGURE 3.3. NO OXIDATION RATE IN AIR

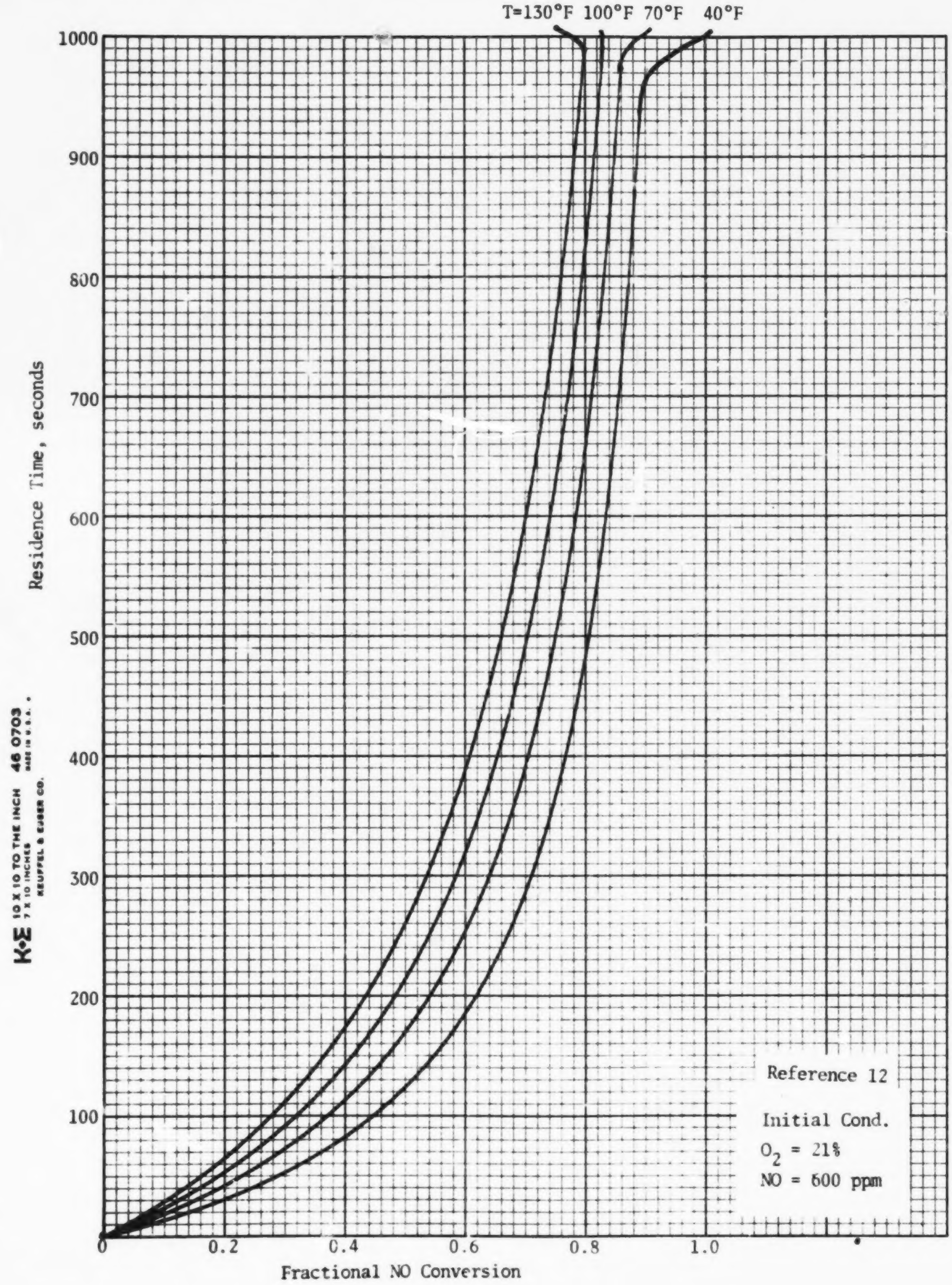
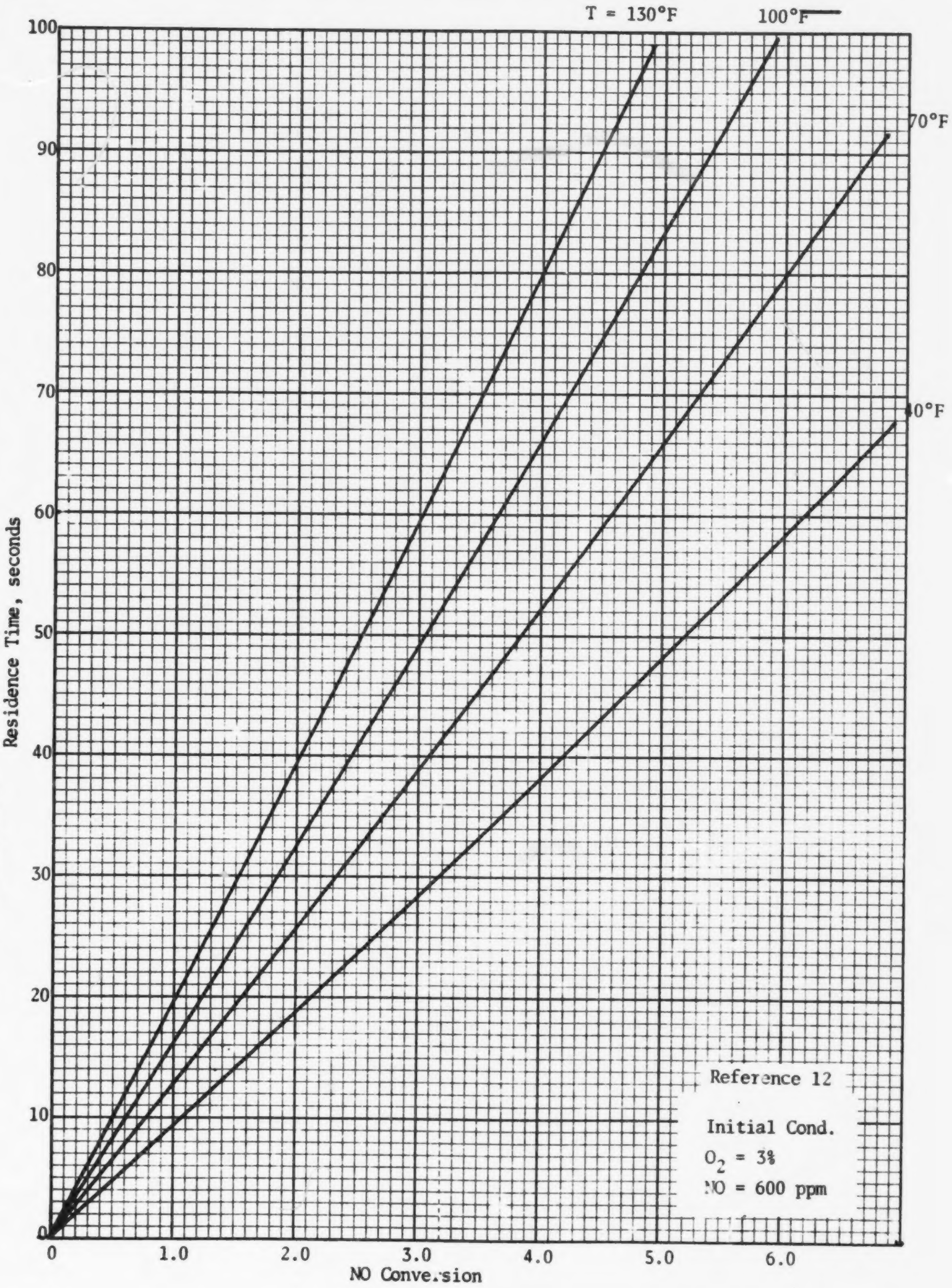
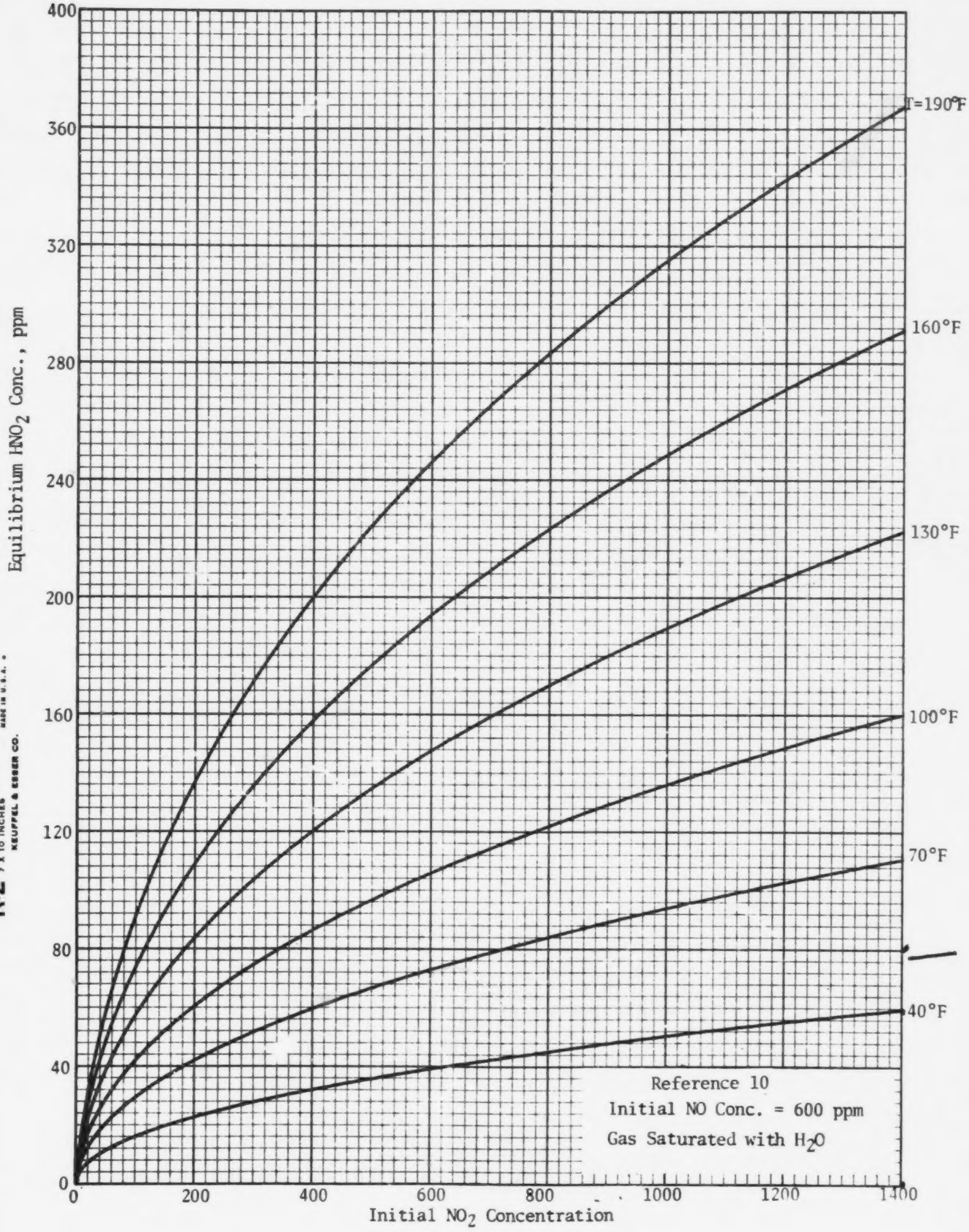


FIGURE 3.4. NO OXIDATION RATE IN FLUE GAS



K+E 10 X 10 TO THE INCH 46 0703
7 X 10 INCHES MADE IN U.S.A.
KEUFFEL & ESSER CO.

FIGURE 3.5. EQUILIBRIUM HNO_2 CONCENTRATIONS



4.0 RESULTS

Since the singular purpose of these tests was to evaluate the feasibility of NO_X absorption in flue gas containing dilute concentrations of SO_2, the NO_X scrubber system was the only equipment which was subjected to variable control. The remainder of the pilot plant was maintained under constant operating conditions. However, some pertinent observations were made with regards to the rest of the system. Therefore, before reporting on the results of the NO_X scrubber, the operation and observation of the particulate scrubber and FBA will be reported. All of the computerized data and results are included in Appendix B.

4.1 OVERALL RESULTS

4.1.1 Particulate Scrubber

The particulate venturi scrubber was operated at about 5 to 6 inches w.g. over the entire course of these tests. The liquid spray rate amounted to 20 gal/MCF. These conditions are comparable to the previous tests.(7) SO_2 performance was also similar. The only difference observed was that while previously the slurry pH varied from 2.0 to 3.5, during these tests the pH varied from 4.0 to 5.5. This is probably due to the presence of an alkaline constituent in the ash.

4.1.2 FBA

During the previous work(8) the FBA was the major subject of study. During the present program its sole function was to reduce the SO_2 concentration to below 50 ppm. To accomplish this a set of operating conditions were specified as follows:

Slurry pH	Greater than 7.0
Liquid-to-Gas Ratio	Greater than 4.0 lb/lb

Unslaked MgO was used exclusively and at a sufficient rate that the pH was maintained at about 8.0. Fly ash slurry from the particulate scrubber was added intermittently. This was done because during the previous work the presence of fly ash in the slurry prevented the formation of deposits in the sump and piping of the FBA. The results of operation of the FBA in this fashion are as follows:

1. Exit SO_2 concentrations were at all times less than 50 ppm. The nominal value was 14.2 ppm.
2. Although no deposition problems were experienced in the FBA piping, for the first time deposition occurred on the underside of the bottom tray. This condition was severe enough to completely close the tray holes. To a lesser extent deposition also began on the underside of the top tray. This material was analyzed by X-Ray diffraction analysis and the results given in Table 4.1. The only identifiable operating difference is the continuous operation at elevated pH's (∿8.0). Only intermittent operation under these conditions was covered in the previous tests. A photograph of the deposit is shown in Figure 4.3.

4.2 NO_X SCRUBBER RESULTS

4.2.1 NO_X Absorption

Because of the analytical problems described in Section 3.2.2, discrimination of the data and evaluation of the degree to which NO_X was absorbed is quite limited. Table 4.2 shows the parameters which were tested and also depicts the run number designation used here. That is, the tests were numbered successively but were assigned a letter which depicts the condition which was to be set up. For instance, Run 10-G was the tenth test and was specified to evaluate NO_X absorption at test condition G in Table 4.2.

The primary results can be summarized as follows:

1. Under none of the conditions tested was any significantly observable reduction in NO_X concentration experienced across the NO_X absorber.
2. The NO_X scrubber operated without difficulty except for a considerable degree of carryover leaving the top of the scrubber. For a period, this carryover affected the analysis by creating a difficult sampling situation.

All of the major results are summarized in Table 4.3. The most interesting factor to note is the NO_X measurements by the NX-130 and the PDS. The former analysis depicts a reduction in NO_X concentration in several tests. Significantly the PDS method not only does not indicate the same reduction but in fact indicates an increase NO_X concentration across the scrubber in several instances. This probably is due to the variance in the PDS method.

4.2.2 SO_2 Absorption

After several of the scheduled tests were completed and the lack of performance was evident, the suitability of the design of the NO_X scrubber became a concern. To evaluate the scrubber design a test was run whereby the scrubber could be evaluated as a sulfur dioxide absorber. This was accomplished by operating the FBA deficient of MgO. Flue gas containing 1350 ppm SO_2 entered the NO_X scrubber. No NO_2 was added to the flue gas. The results are shown in Figure 4.2. These results reveal several facts. First, the K_ga for SO_2 absorption although only about one third as great as for the FBA is still adequate to produce large and measurable changes in SO_2 concentration. Secondly, the fact that SO_2 absorption changed significantly with changes in the liquid spray rate means that either the wetted area changes significantly with the liquid spray rate or that a significant liquid-phase effect is present. This liquid-phase dependence could be either the liquid-phase diffusion coefficient k_2 or a reaction rate effect such the following:

$$MgO_{(s)} + H_2O \rightarrow Mg^{++} + 2OH^- \qquad (4\text{-}1)$$

$$SO_2 \cdot H_2O + 2OH^- \rightarrow SO_3^{=} + 2H_2O \qquad (4\text{-}2)$$

Reaction (4-1) represents the dissolution of MgO which could be the limiting step in either the SO_2 absorption or NO_X absorption systems.

Although no data exists with regards to the diffusivity of HNO_2 in the gas phase, if it does not differ greatly from SO_2 (by a factor of 2 to 3), then the SO_2 results will be useful in interpreting the NO_X results as will be shown in the following section.

TABLE 4.1. ANALYSIS OF DEPOSIT SAMPLES

Chem Lab No.	M-24801	M-24802	M-24803
Sample Description	Soft Sample from Center	Incipient Deposit from Corner	Bulk Sample from Edge
X-Ray Diffraction (Crystalline Constituent)			
Major	$MgSO_3 \cdot 6H_2O$	$MgSO_3 \cdot 6H_2O$	$MgSO_3 \cdot 6H_2O$

TABLE 4.2. PARAMETER STUDY SPECIFICATIONS

Test Condition	NO_2/NO	L/G	Stoich.	Recirc. Slurry Conc.	Load	Number Tests
A	1.0	15	1.5	2.5%	100%	4
B	0.7	↓	↓	↓	↓	1
C	0.0	↓	↓	↓	↓	2
D	1.3	↓	↓	↓	↓	1
E	1.0	10	↓	↓	↓	1
F	↓	5	↓	↓	↓	1
G	↓	15	2.0	↓	↓	1
H	↓	↓	3.0	↓	↓	1
I	↓	↓	1.5	5	↓	1
J	↓	↓	↓	10	↓	1
K	↓	↓	↓	2.5	50	2
						16 Two Tests/Day

TABLE 4.3. SUMMARY OF RESULTS

Test Number	1-C	2-A	3-E	4-F	5-K	6-L	7-C	8-B	9-D	10-G	11-H	12-A	13-A	14-I	15-A	16-K	17-J
NO_X by PDS																	
FBA Exit	124.8	420.7		502.4	589.4		563.4	580.4		608.8	469.5	501.6	580.9	528.6	547.5	627.7	576.6
NO_X Scrubber Inlet	233.4	1122.1	969.3	759.5	671.3		504.1	906.0	1026.2	766.0	913.9		525.8	1310.9	971.8	866.3	1194.6
NO_X Scrubber Exit	209.1	901.3	1180.9	855.0	920.6		550.4	947.5	717.5	1709.5	274.1	762.0	580.3	1076.8	1136.4	886.4	1223.1
NO_X by Saltzman																	
NO_X Scrubber Inlet		876.9	930.3	613.9	901.6		324.2	802.1	937.1	680.8	696.2	442.0	662.5	689.1	694.9	642.5	609.6
NO_X Scrubber Exit			986.7	751.1	1226.1		311.1	566.9	857.8	491.6	509.7		256.4	492.4	471.8	449.4	451.1
NO_X by Fuel Cell																	
Furnace Exit	870.3	485.8	485.6	561.9	588.1		733.2	759.6		692.4	748.7	748.6	674.2	648.7	785.5	715.7	815.7
FBA Exit	902.0	485.8	504.3	486.9	559.6		695.6	873.6		645.6	664.4	655.0	730.4	614.9	835.8	403.2	704.9
NO_X Scrubber Inlet	686.0	803.4	644.4	580.6	777.8		714.4			729.9	786.1	842.2	664.8		795.6	846.8	856.0
NO_X Scrubber Exit	635.2	308.3	551.1	299.7	398.4		629.8		773.6	655.0	505.3	617.6	725.7		845.9	514.1	916.4
Ratio NO_2/NO																	
PDS	0.87	1.67		0.51	0.14		-0.11			0.26	0.95		-0.09	1.48	0.78	0.38	1.07
F.C. & Rotameter	0.00	2.29	2.24	1.55	1.45		0.00			0.65	0.65	0.67	0.63	0.76	0.59	0.92	0.70
SO_2 by Barton																	
Furnace Exit	1007.6	1862.4	1649.6	1538.4			1799.0	1688.7	698.0	1783.4	1801.2	1741.8	1713.5	1704.6	1675.5	1643.2	1951.5
Particulate Scrubber Exit	1138.6	1720.0		1431.0			1614.5	1557.1	698.0	1595.7	1479.5	1479.5	1116.7	1587.7	1369.9		1692.4
FBA Exit	10.3	3.5	9.4	10.3		1308.8	21.2	13.2	4.2	4.1	30.9	30.9	8.5	2.0	18.4	14.2	18.9
NO_X Scrubber Exit	6.0					22.8	8.3										
Gas Residence Time, sec	2.22	2.10	2.22	2.32	2.50	2.10	2.22	2.22	2.22	2.22	2.22	2.22	2.32	2.32	2.32	3.08	2.32
Gas Velocity, fps	1.8	1.9	1.8	1.7	1.6	1.9	1.8	1.8	1.8	1.8	1.8	1.8	1.7	1.7	1.7	1.3	1.7
L/G, lb/lb	21.4	19.2	13.6	8.5	12.5	19.1	19.9	20.2	20.2	19.9	20.3	20.4	22.0	22.0	21.5	17.6	21.8
Ratio Nitrite/Nitrate (Liq)	11.739	0.534	1.632	3.857	6.000	0.000		6.533	41.333	9.167	4.407	4.321	5.889	5.750	6.833	6.000	4.674
Flue Gas Flow Rate, lb/hr	3508.0	3913.0	3748.0	3541.0	3260.0	3927.0	3772.0	3719.0	3715.0	3761.0	3688.0	3684.0	3466.0	3460.0	3518.0	2726.0	3466.0

FIGURE 4.1. DEPOSITION ON UNDERSIDE OF FIRST FBA STAGE

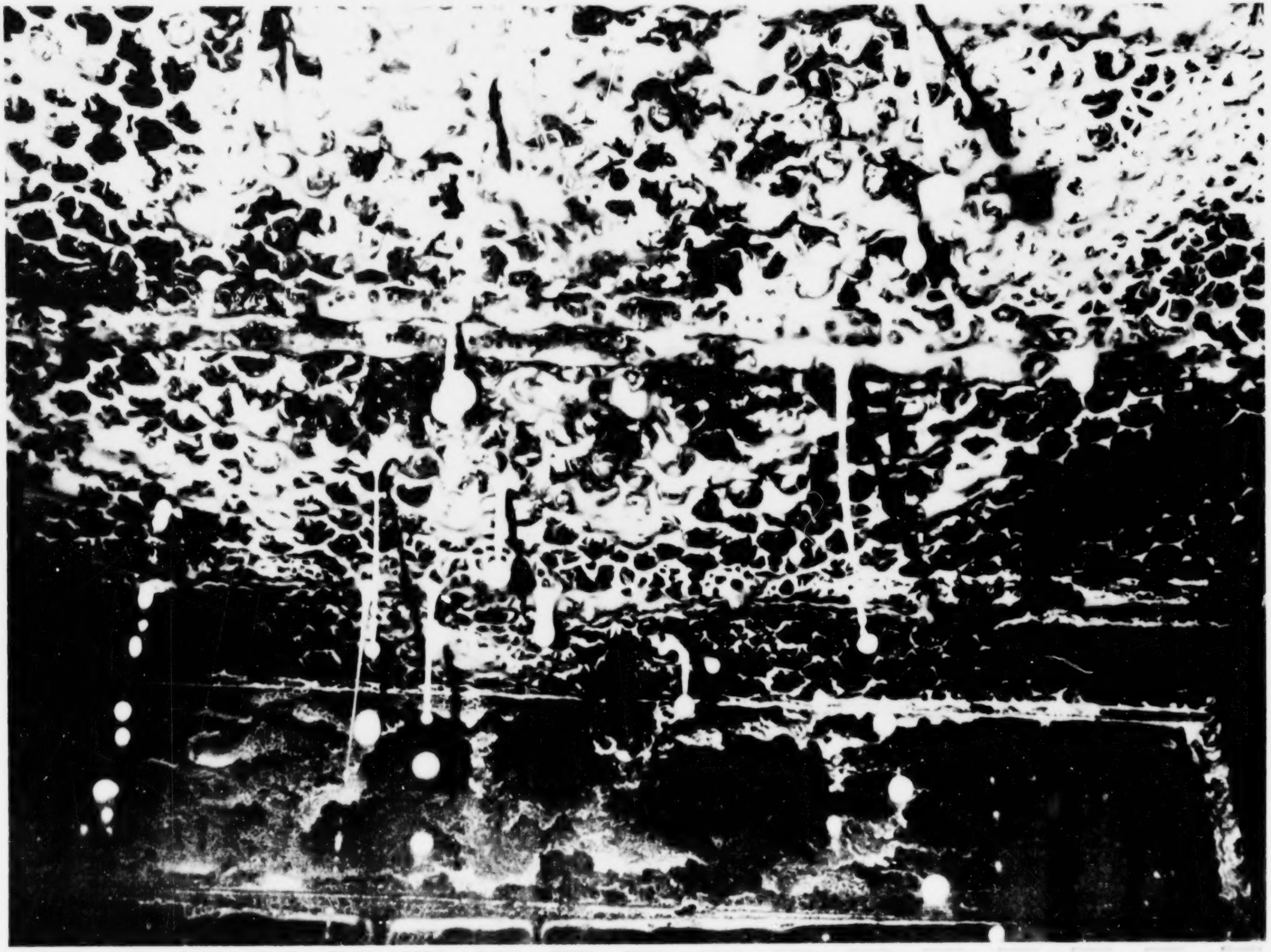
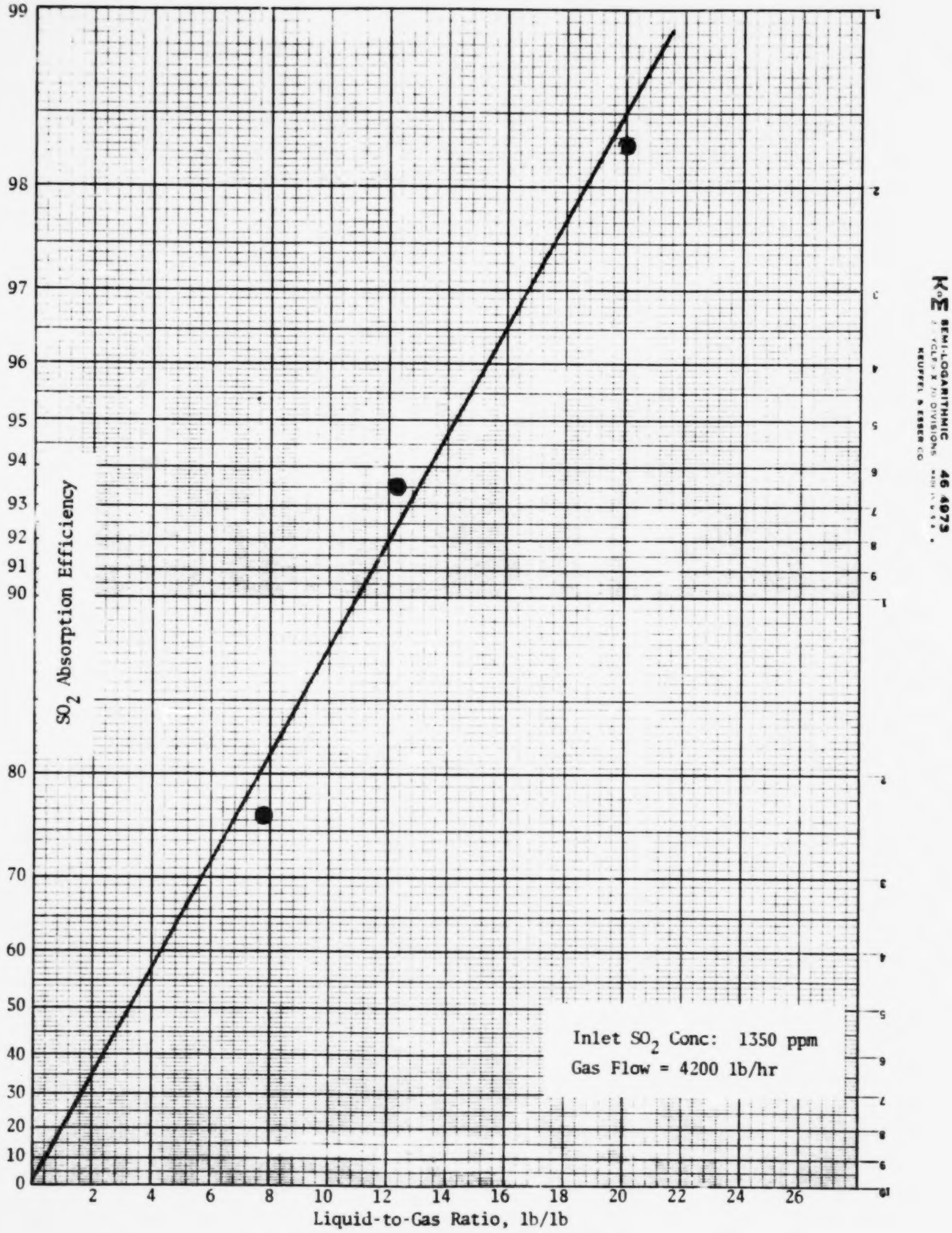


FIGURE 4.2. SO_2 ABSORPTION IN NO_X SCRUBBER



5.0 DISCUSSION

The purpose of the program was to experimentally study the feasibility of absorbing NO_X into magnesia slurry. Since the results were largely negative, the task remaining is to establish the degree to which these results reflect upon the general feasibility of NO_X absorption by wet scrubbing. That is, it can certainly be concluded that NO_X absorption into MgO in the apparatus tested is unsatisfactory and is therefore not a feasible approach. However, to what extent does the equipment design and the choice of alkali affect the feasibility of NO_X absorption by alkali scrubbing?

To approach this question a mechanism for this absorption must first be postulated. The model for which this research work was based and which is still felt to be valid is presented here.

It is well known that NO absorption into any aqueous medium is very slow owing to its extremely low solubility in water. Secondly, several people have studied NO_2 absorption, particularly with respect to nitric acid manufacture. Absorption is known to diminish rapidly with decreasing NO_2 partial pressure. NO_2 absorption efficiency greater than 50% is difficult to attain when inlet NO_2 concentrations are less than 1000 ppm. However, several experimenters have noted that NO_X absorption is enhanced when equimolar concentrations of NO and NO_2 are present in the gas phase. Quite obviously any absorption enhancement must be the result of a reaction between NO and NO_2 forming a substance more readily absorbed than either of the two reactants. That reaction is believed to be the following:

$$NO + NO_2 + H_2O \rightarrow HNO_2 + HNO_2 \qquad (5\text{-}1)$$

In the wet scrubbing environment water vapor is present at very substantial levels. The above reaction probably takes place in two steps:

$$NO + NO_2 \rightarrow N_2O_3 \qquad (5\text{-}2)$$

$$N_2O_3 + H_2O \rightarrow HNO_2 + HNO_2 \qquad (5\text{-}3)$$

Little is known of the kinetics of reaction (5-1) except for the work done by Wayne.(10) He studied the formation of HNO_2 at 25°C and found the forward rate to be $k_f = 7.4 \times 10^4$ atm^{-2} sec^{-1}. Therefore, equimolar concentrations of NO and NO_2 initially at 1000 ppm each in a flue gas saturated with water vapor at 130°F and assuming that k_f equals its 25°C value, it would take 1.6 seconds to reduce the NO + NO_2 concentration to 200 ppm total. This conversion time is the first clue as to the contact time required for an NO_X scrubber relying on reaction (5-1).

However, gas-phase kinetics are not the only factor of importance in this system. First, it should be noted that chemical thermodynamics show that reaction (5-1) is reversible and in fact in the conditions under question conversion is relatively low (5 to 15%). This means that the HNO_2 concentration driving force for mass transfer will be severely limited. Finally, the gas absorption mass transfer rate of HNO_2 into the alkali solution can easily be limiting by this system for any one of several reasons. The first is quite obviously the small gas-phase driving force available; the second is the possible MgO dissolution lags; and the third follows from the long gas side residence times required which necessitates low gas Reynolds numbers which in turn create poor gas side mixing and mass transfer conditions.

The material balances for NO, NO_2, and HNO_2 across an element of volume as shown in Figure 5.1 lead to the following set of equations:

For HNO_2,

$$\frac{dy_1}{dZ} = \frac{1}{v_g} \left\{ r_1 - \frac{k_{1g}a}{\rho_g} (y_1 - y_1^*) \right\} \tag{5-4}$$

For NO,

$$\frac{dy_2}{dZ} = \frac{-1}{v_g} \frac{r_1}{2} \tag{5-5}$$

For NO_2,

$$\frac{dy_3}{dZ} = \frac{-1}{v_g} \left\{ \frac{r_1}{2} + \frac{k_{2g}a}{\rho_g} (y_2 - y_2^*) \right\} \tag{5-6}$$

where y_1 = HNO_2 molar concentration = p_1/p_T

y_2 = NO molar concentration = p_2/p_T

y_3 = NO_2 molar concentration = p_3/p_T

v_g = gas velocity, ft/sec

r_1 = kinetic rate of formation of HNO_2

ρ_g = molar density of bulk flue gas

a = specific mass transfer surface area, ft^2 surface/ft^3 scrubber volume

k_{1g} = gas-phase mass transfer coefficient for HNO_2

k_{2g} = gas-phase mass transfer coefficient for NO_2

y_1^* = HNO_2 gas concentration at the gas-liquid interface

y_2^* = NO_2 gas concentration at the gas-liquid interface

Now the kinetic rate of formation of HNO_2 is developed as follows:

Forward reaction:

$$\left.\frac{dy_1}{dZ}\right|_{Forward} = k_f\, y_2\, y_3\, H \qquad (5\text{-}7)$$

Reverse reaction:

$$\left.\frac{dy_1}{dZ}\right|_{Reverse} = \frac{-k_f}{K_{eq}}\, y_1^{\,2} \qquad (5\text{-}8)$$

where $K_{eq} = \frac{k_f}{k_r}$ = equilibrium constant

k_r = reverse reaction rate constant

H = molar water vapor concentration p_V/p_T

$\therefore$

$$r_1 = k_f\, y_2\, y_3\, H - \frac{k_f}{K_{eq}}\, y_1^{\,2} \qquad (5\text{-}9)$$

Several factors are significant from these equations (5-4) through (5-9). From equations (5-4) and (5-9) it is seen that if k_f is fast enough to maintain instantaneous equilibrium then the limiting factor will surely be the mass transfer rate. The maximum value of y_1 will be the equilibrium value.

From equation (5-5) it is seen that the only mechanism for reducing the NO concentration is to form HNO_2 which means, of course, that it is dependent on both the reaction rate and the mass transfer rate of HNO_2.

Equation (5-6) accounts for the fact that NO_2 can absorb directly in alkali solution. NO_2 absorption would be detrimental to the process in question since it would defeat the purpose of injecting NO_2 into the flue gas in the first place. Since experience has shown equimolar NO-NO_2 absorption to be superior to NO_2 absorption alone, it is evident that NO_2 absorption must be substantially greater than k_{2g}. It would seem more likely that since NO_2 is substantially less soluble in water than HNO_2, then it follows that $y_2 - y_2^*$ must be small compared to $y_1 - y_1^*$ (in spite of the small value of y_1). The relative degree to which these two constituents were absorbed in the present experiment can be examined from the product liquid analysis. NO_2 absorption will produce equimolar quantities of nitrite (NO_2^-) and nitrate (NO_3^-) in solution while HNO_2 absorption will produce only nitrite. See Table 4.2 for this ratio (NO_2^-/NO_3^-). These results confirm that HNO_2 was the predominant species absorbed.

To apply the above model to the present experimental situation, the following simplifying assumptions were made:

1. NO_2 absorption was negligible relative to HNO_2 absorption (supported by liquid analysis).
2. $y_1^* = 0$ (no liquid film or reaction effects). This is a weak assumption but will provide a limiting solution to the present case.
3. The geometry depicted in Figure 5.1 was used.
4. The surfaces were assumed to be fully wetted.

The model was applied to typical operating conditions as follows:

v_g = 2 ft/sec
T = 130°F
H = 0.151 moles water vapor/mole wet gas
ρ_g = 0.00232 lb moles/ft^3
K_{eq} = 0.465 atm^{-1}
a = 10 ft^2/ft^3

The mass transfer coefficient k_{1g} was determined from the Sherwood equation where:

$$N_{SH} = 0.023\, N_{Re}{}^{0.8}\, N_{SC}{}^{0.44} = \frac{k_c D}{D_f}$$

$$N_{Re} = 2480$$

$$N_{SC} = 0.94$$

∴ N_{SH} = 10.6
D_{eq} = 0.25 ft
D = 0.2 cm^2/sec

∴ k_c = 4.56 x 15^{-3} ft/sec
k_{1g} = 0.0764 lb mole/hr ft^2

Equations (5-4) through (5-9) were solved by numerical integration on an IBM 360 computer and showed that NO_X absorption would only be 2% for this case. The calculated $k_g a$ is only 0.764. This is an extremely low mass transfer coefficient. However, from the single SO_2 absorption experiment it is possible to obtain a measured value of $k_g a$ for this device. For comparable liquid recirculation rates the SO_2 experiment demonstrated a $k_g a$ equal to 15.8 lb moles/hr ft^3. Adjusting for differences in the expected diffusivities, the $k_g a$ for HNO_2 absorption would be as follows:

$$k_g a_{HNO_2} = k_g a_{SO_2} \left(\frac{D_{HNO_2}}{D_{SO_2}}\right) = 15.8 \left(\frac{0.20}{0.138}\right) = 23.0 \text{ lb moles/hr ft}^3$$

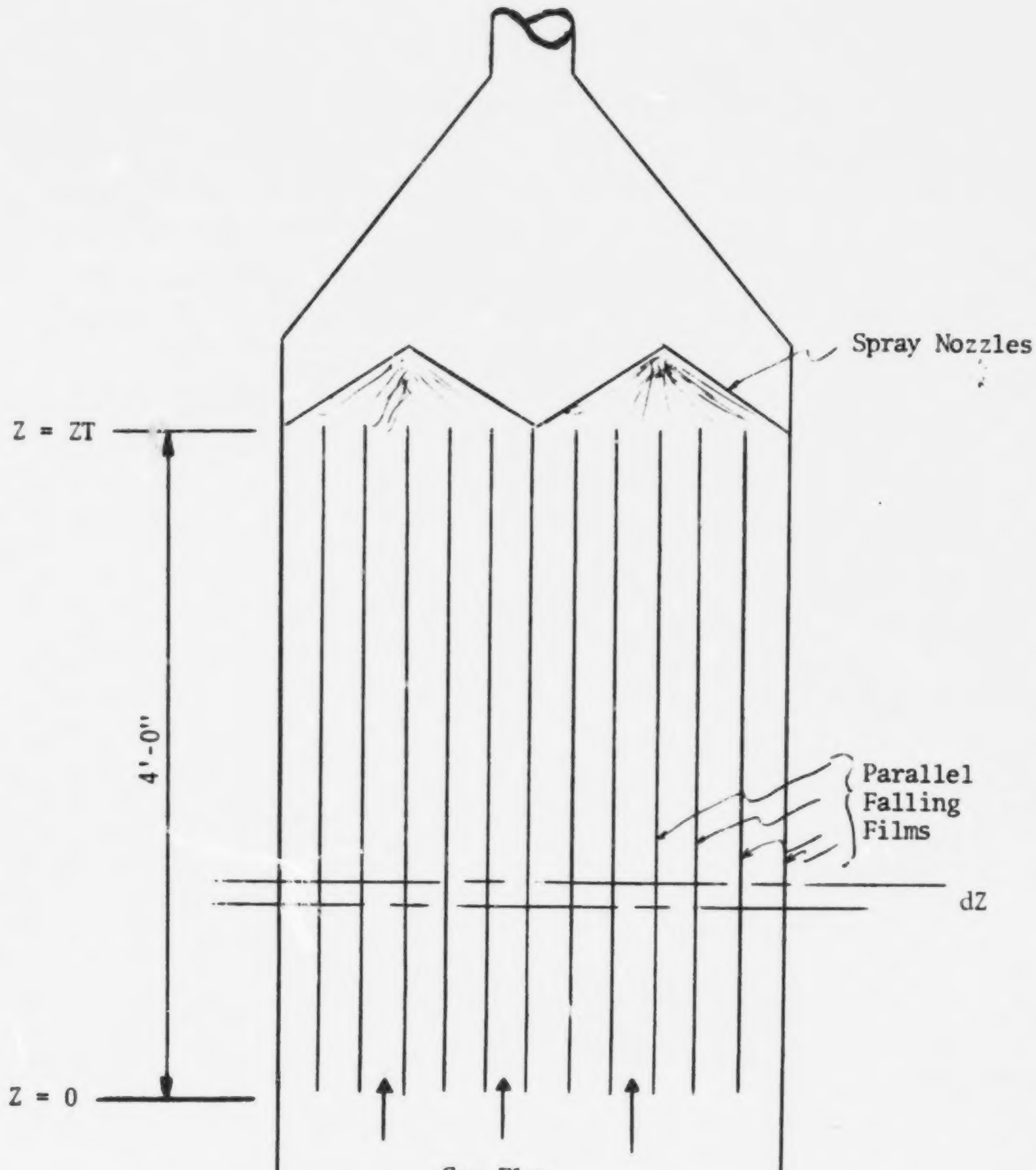
This $k_g a$ is nearly 30 times larger than that calculated from theory. This is obviously a better measure of $k_g a$ than the theoretical value. However, for this condition the NO_X absorption should have been 33%. For this magnitude of NO_X reduction, the measured change in total NO_X concentration across the scrubber would surely have been apparent in spite of the analysis difficulties. The conclusion to be drawn here is that a significant liquid film resistance must be present in the HNO_2 absorption situation. That is equivalent to saying that y_1^* is not negligible. To include y_1^* as a system variable would greatly increase the complexity of this model because it would require the coupling on liquid side material balances, liquid side diffusion equations, and liquid side chemical reaction kinetics. If it can be assumed that y_1^* is a linear function of y_1 for a fixed set of liquid and gas flow rates, then the $k_g a$ in equation (5-4) will be reduced by a constant and the solution to these equations will still be valid.

To evaluate the expected NO_X absorption performance over a broad range of $k_g a$'s and k_f's, this model was applied to the subject scrubber geometry and the results plotted in Figure 5.2. From this figure and from some facts regarding the process material balance, the potential feasibility of NO_X absorption in the subject apparatus can be established. First, consider the flow sheet in Figure 5.3 which depicts the minimum unit operations required of the process. The process design established the criterion that the NO_2 flow to the flue gas is just sufficient (no excess NO_2) to produce an equimolar quantity of NO and NO_2. Then the minimum NO_X absorption efficiency which will produce a self-sustained supply of NO_2 is 75%. This, however, will produce an overall NO_X efficient of only 50%. The NO_X concentration leaving the scrubber which will be acceptable to regulating agencies in light of the fact that 50% of the NO_2 would leave as NO_2, is highly questionable. Deferring the above question and addressing the question to technical feasibility only, the 75% absorption efficiency is the minimum acceptable scrubber performance. Then from Figure 5.2 it is seen that for $k_f = 7.3 \times 10^4$ atm^{-2} sec^{-1}, the $k_g a$ will have to be in excess of 72 lb moles/hr ft^3. This is as much as 100 times the apparent $k_g a$. There appears to be no physical manner in which sufficient contact surface area could be packed into a scrubber of this type to increase the k_ga appreciably. It would appear that the system is liquid film mass transfer or chemical reaction rate limiting and at least for the MgO base, would probably not perform even under very extreme design changes. If the MgO dissolution step is the limiting factor, then for a soluble base such as sodium carbonate the apparent k_ga would only need to be increased from 23 lb mole/hr ft^3 to 72 lb mole/hr ft^3. This is certainly a feasible physical possibility. For a soluble base, a packed tower seems to be the most appropriate device for this function.

Summarizing, it is concluded that NO_X absorption into a slurry of MgO is not a technically feasible approach for power plant application within the confines of reasonable equipment design. However, based upon the arguments presented above, it is quite possible that NO_X absorption into a soluble alkali base may be feasible. The appropriate apparatus would seem to be a conventional packed tower.

A final factor which can be drawn from the above analysis is that the absorption process can be highly temperature dependent. Increasing temperature will increase the water vapor concentration, the forward reaction rate constant, the equilibrium conversion of HNO_2, and finally the gas-phase diffusion coefficient. All of the above, of course, will increase HNO_2 absorption.

FIGURE 5.1. GEOMETRY ASSUMED FOR NO_X ABSORPTION


Spray Nozzles
Z = ZT
4'-0"
Parallel
Falling
Films
dZ
Z = 0
Gas Flow

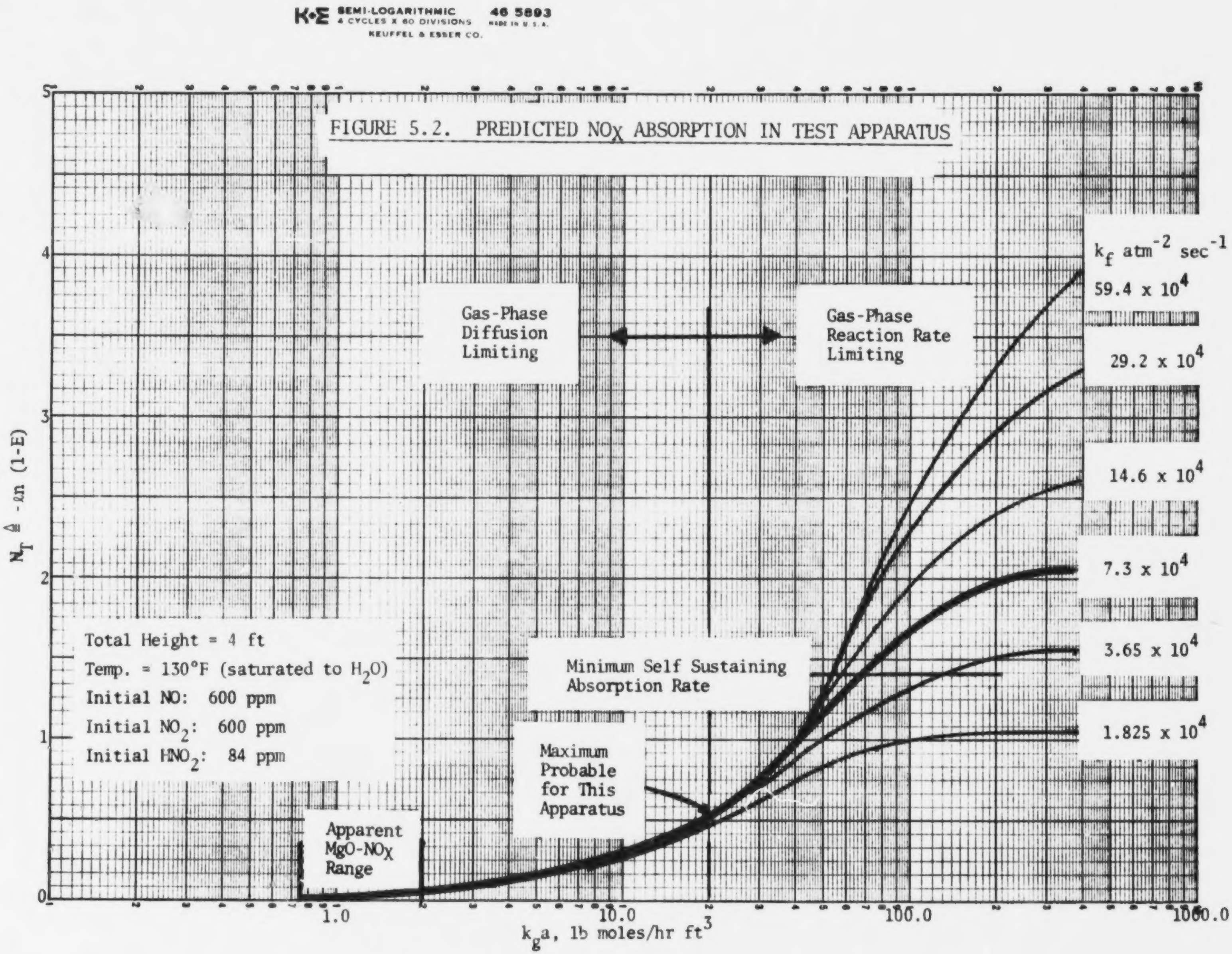
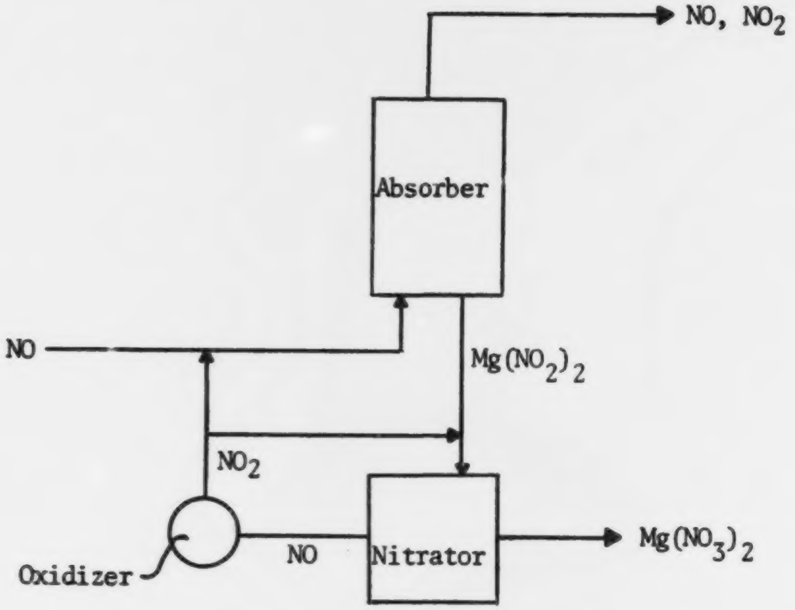


FIGURE 5.2. PREDICTED NO_X ABSORPTION IN TEST APPARATUS

FIGURE 5.3. PROCESS FLOW SCHEMATIC


NO, NO2
Absorber
NO
Mg(NO2)2
NO2
Nitrator
Mg(NO3)2
Oxidizer
NO

Absorber: $NO + NO_2 + MgO \rightarrow Mg(NO_2)_2$

Nitrator: $3Mg(NO_2)_2 + 2H_2O \rightarrow 4NO + Mg(NO_3)_2 + 2Mg(OH)_2$

Absorber Efficiency	75*	80	85	90	95	99
Process Efficiency	50	60	70	80	90	98

---

* Minimum acceptable performance for self sustaining NO_2 supply.

6.0 CONCLUSIONS

1. NO_X absorption with equimolar concentration of NO and NO_2 into MgO slurry is unfeasible in the apparatus tested. It is probably unfeasible in any practical gas-slurry contacting apparatus.
2. NO_X absorption into soluble alkalis may be feasible and would best be done in packed towers.

7.0 RECOMMENDATIONS

1. MgO slurry should be removed from those bases being considered for aqueous NO_X absorption.
2. Work should continue on the feasibility evaluation of soluble bases for this system.

jlz

Submitted by: W. Downs/jlz
W. Downs

Approved by:
H. P. Markant

REFERENCES

1. W. Downs and A. J. Kubasco, "Magnesia Base Wet Scrubbing of Pulverized Coal Generated Flue Gas - Pilot Demonstration," Final Report to NAPCA under Contract CPA-22-69-162, Alliance Research Center Report 5153, pp. 2-1 through 2-17, September 28, 1970.

2. Ibid., p. 2-1.

3. Ibid., p. 3-3 through 3-5.

4. Ibid., p. 3-5 through 3-6.

5. S. S. Strom, "Catalytic Reduction of Nitrogen Dioxide with Ammonia," MS Thesis, University of Cincinnati, June, 1966, pp. 18-22.

6. W. Downs, op. cit., pp. 3-11 through 3-15.

7. Ibid., p. 4-1, pp. 4-13 through 4-14.

8. Ibid.

9. Ibid., p. 4-8.

10. L. G. Wayne and D. M. Yost, J. Chem. Phys. 18, pp. 767-768, 1950.

11. B. E. Saltzman, Anal. Chem., 26, No. 12, pp. 1949-1955, December 1954.

12. U. S. Department of Health, Education, and Welfare, Public Health Service, Selected Methods for the Measurement of Air Pollutants, PAS Publication No. 999-AP-11, 1965, pp. C1-C7.

APPENDIX A

DETERMINATION OF NO_X: SALTZMAN METHOD

Introduction

The Saltzman method is intended for the manual determination of nitrogen dioxide in the atmosphere in the range of a few parts per billion (ppb) to about 5 ppm by changing the sample size, though the range can be increased to about 10,000 ppm. This method is also applicable to the determination of nitric oxide after it is oxidized to nitrogen dioxide. The nitrogen dioxide is absorbed in Griess-Saltzman reagent. A stable pink color is produced within 15 minutes and may be read visually or in an appropriate instrument. Only slight interfering effects occur from other gases.

Reagents

All reagents are made from analytical-grade chemicals in nitrite-free water prepared, if necessary, by redistilling distilled water in an all-glass still after adding a crystal of potassium permanganate and barium hydroxide. They are stable for several months if kept well stoppered in brown bottles in a refrigerator. The absorbing reagent should be allowed to warm to room temperature before use.

N-(1-Naphthyl) - Ethylenediamine Dihydrochloride, 0.1%

Dissolve 0.1 g of the reagent in 100 ml of water. This is a stock solution.

Sulfanilic Acid, 0.5%

Dissolve 5 g of sulfanilic acid in almost a liter of water containing 140 ml of glacial acetic acid. Gentle heating is permissible, if desired, to speed up the process. Cool and dilute to 1 liter with water.

Absorbing Reagent

Add 10 ml of the N-ethylenediamine dihydrochloride stock solution to a 500-ml volumetric flask and dilute to mark with the 0.5% sulfanilic acid. Mix just before use and discard at end of each day!

Standard Sodium Nitrite Solution, 0.0203 g/Liter

One ml of this working solution produces a color equivalent to that of 10 ml of nitrogen dioxide (10 ppm in 1 liter of air at 760 mm of mercury and 25°C). Prepare fresh just before use by dilution from a stronger stock solution containing 2.03 g of the reagent grade granular solid (drying is unnecessary) per liter. The stock solution should be stable for 90 days.

Apparatus

Spectrophotometer or Colorimeter

A laboratory instrument suitable for measuring the pink color at 550 mm, with stoppered tubes or cuvettes, is recommended.

10 or 20 ml Gas Tight Syringe

Hamilton type, for measuring gas samples.

100-ml Serum Bottle

Needle-puncture rubber stoppers, sleeve type, for serum bottles.

Analytical Procedure for Nitrogen Dioxide

Sampling Procedure

Pipet exactly 10 ml of absorbing reagent into a serum bottle and stopper bottle with rubber stopper. Inject 10 ml of the sample gas with the syringe and shake bottle vigorously. If the gas sample has an expected concentration of about 500 ppm, a 10-ml gas sample will yield an absorbance very near the standard. If the concentration is higher, use a smaller sample proportionally. If the gas sample temperature and pressure deviate greatly from 25°C and 760 mm Hg, measure and record the values.

Determination

After collection and absorption of the sample a pink color appears. Color development is complete within 15 minutes at ordinary temperatures. Transfer to cuvettes and read in a spectrophotometer at 550 mm using unexposed absorbing reagent as a blank. Colors may be preserved, if well stoppered, with only 3 to 4% loss in absorbance per day; however, if strong oxidizing or reducing gases are present in the sample in concentrations considerably exceeding that of the nitrogen dioxide, the absorbance should be determined as soon as possible to minimize any bleaching.

Standardization

Add graduated amounts of the working standard sodium nitrite solution up to 1 ml (measured accurately in a graduated pipet or small buret) to a series of the serum bottle containing 10 ml of the absorbing reagent. Mix, allow 15 minutes for complete color development, and read the absorbance.

APPENDIX B

COMPUTER OUTPUT

```
                         MAGNESIUM BASE SLURRY SCRUBBING PROGRAM-OUTPUT DATA PAGE 1

  RUN NUMBER   1-C          DATE 9-11-71      TIME OF DAY 1530

 FLUE GAS DATA               FLOW    TEMP.     SO2     SO3     NOX    FLYASH     HUM.     DEW     DRY      STAT
                             #/HR     F        PPM     PPM     PPM    GR/DSCF    #/#     POINT    FLOW     PRES
                                                                                           F      #/HR    IN.H2O
   PRIMARY AIR                454.   160.0  ------   -----   -----   -------    0.016    74.8     447.      8.1
   SECONDARY AIR             4595.   690.0  ------   -----   -----   -------    0.016    75.6    4522.      6.3
   FURNACE EXIT              5452.   680.0  1007.6   *****   *****   *******    0.059   116.9    5150.      2.6
   PART.SCRB.INLET           5452.   565.0  ******   *****   *****   *******    0.059   116.9    -----      2.7
   PART.CYC.EXIT             3274.   148.0  1138.6   *****   *****   *******    0.159   147.9    2825.     -6.8
   VENT ABS.INLET            *****  ******  ******   *****   *****   *******   ******   *****    -----     *****
   ABS CYC.EXIT              *****  ******  ******   *****   *****   *******   ******   *****    -----     *****
   FLOATING BED IN           3274.   150.0  ******   *****   *****   *******    0.159   147.9    -----     -8.1
   FLOATING BED EX           3686.     0.0  ******   *****   *****   *******    0.196   153.4    -----    -16.3
   P.P. EXIT ORIF.           3686.   138.0    10.3   *****    125.   *******    0.196   153.4    3081.    -16.3

 SCRUBBER STREAM DATA                                               VENTURI ABSORBER       FBA
   PARTICULATE             TEMP,F    FLOW,GPM       GAS ABSORBER    TEMP,F FLOW,#/M   TEMP,F  FLOW,#/M
    MAKEUP WATER            60.0        0.0          MAKEUP WATER    *****   *****      60.0      0.6
    PRODUCT LIQ.           142.0        0.0          MAKEUP MGO SL.  *****     3.1      92.0      3.1
    RECIRCULATED LIQ.      142.0       19.78         PRODUCT LIQ.    *****   *****     142.0      0.0
                                                     REC.(SPRAY NOZ) *****   *****     142.0    520.0
                                                     REC.(FLOW NOZ.)         *****              355.0

 FURNACE PERFORMANCE                       SCRUBBER PERFORMANCE      PART.    VENT ABS.    FLOAT.BED
   HEAT RELEASE,BTU/HR    0.535E 07          SO2 ABSORB.EFF        -13.01     ******         99.09
   %  FUEL AS COAL             96.5          FLYASH COL.EFF        ******     ******        ******
   COAL FLOW RATE,#/HR        423.7          SO3 ABSORB.EFF        ******     ******        ******
   NAT.GAS FLOW,#/HR            8.6          NOX ABSORB.EFF        ******     ******        ******
   %   EXCESS AIR              14.8          GAS VELOCITY,FPS        91.8     ******           6.3
   OXYGEN,%DRY,MEAS.           3.10          LIQ/GAS,GAL/MCF         21.7     ******          52.6
   CO2,%DRY-CALC.             15.39          LIQ/GAS,#/#              3.0     ******           5.8
   HUMIDITY,#/# - CALC.       0.059          PRES.DROP,IN.WG          2.7     ******           5.3

SO2 ABSORPTION PARAMETERS.                                      SULFATE FORMATION PARAMETERS
  VENTURI ABSORBER                FLOATING BED ABSORBER
                                                                  CONC.,GM-MOLE/L=   ******
  KGA,#MOLE/HR-FT3,    = ******   KGA,#MOLE/HR-FT3       =    30.0   MOL% TOTAL SULF=   *****
  SULFITE/SO2-MOL/MOL = ******    SULFITE/SO2-MOL/MOL    =   27.98   O2 AT FURN. EX.=    3.10
  SUMP RESID.TIME,MIN = ******    SUMP RESID.TIME,MIN    =  ******   O2 AT ABSORB.IN=   *****
                                                                  O2 AT ABSORB.EX=   *****

 ***** MEANS ITEM NOT MEASURED
```

```
              MAGNESIUM BASE SLURRY SCRUBBING PROGRAM - OUTPUT DATA PAGE 2

   RUN NUMBER   1-C          DATE 9-11-71     TIME OF DAY 1530

MATERIAL BALANCES                                                  INPUT FOR EQ. - KIN.PROG.
                      SULFUR   MAGNESIUM  FLYASH    WATER    DRY GAS
  FURNACE                                                          INPUT FLOWS,#ATOMS/100#FEED
    INPUT,#/HR        15.68     ------     31.36    284.0     5142.      CARBON      0.477223
    OUTPUT,#/HR        5.41     ------    ******    302.4     5150.      HYDROGEN    0.620751
                                                                         OXYGEN      1.393074
  PART.SCRUBBER                                                          NITROGEN    5.046655
    INPUT,#/HR         5.41     ------    ******     345.     5150.      SULFUR      0.009072
    OUTPUT,#/HR        3.35     ------    ******     449.     2825.
                                                                      FEED RATE,#/SEC=   1.50
  SO2 ABSORBERS
    INPUT,#/HR         3.35       7.53    ******     658.     2825.   ENTHALPY,BTU/# =   -4412.
    OUTPUT,#/HR        0.03     ******    ******     605.     3081.
*
*SO2 ABSORBERS-      GM SO2/   GM-MOLE/     GRAM/      MAKEUP MGO COMPOSITION
 PRODUCT COMP.       100ML     LITER        100ML        SLURRY CONC.- GM MGO/100ML =      6.75
                                                         MGO PRESLAKED, NO=0, YES=1 .         0
 TOTAL,               4.12     0.6440      ------        % SLAKED TO MG(OH)2,MEAS.  =    ******
 COMBINED             4.12     0.6440      ------
 FREE                 0.0      0.0         ------      PRODUCT MG BASE PHYSICAL PROPERTIES
 MONO(TOTAL)          4.12     0.6440      ------        ACID STRENGTH, PH      =    8.00
 MONO(DISSOLVED)      0.96     0.1500       1.560        SP.GRAVITY,HYDROM.     =    1.0700
 MONO(SOLID)          3.16     0.4940      10.473
 BISULFITE            0.0      0.0          0.0
 MGO                  1.23     0.1929       0.771
 SULFATE             *****     ******      ******      PARTICULATE SCRUBBER PRODUCT
 MAGNESIUM            5.36     0.8369      ------        ACID STRENGTH , PH     =   5.40
 FLYASH              -----     ------      ******        FLYASH CONC. GM/100ML  =   6.50
 SOLIDS,MG           -----     ------      18.457

 COAL COMPOSITION-MASS

   CARBON      0.7150
   HYDROGEN    0.0485
   OXY+NIT     0.0817
   SULFUR      0.0370
   ASH         0.0740
   WATER       0.0438

*
*SOLIDS FREE BASIS, MASS/VCLUME SOLUTION
```

```
RUN NUMBER   1-C          DATE 9-11-71      TIME OF DAY 1530

FLUE GAS DATA     FLOW    TEMP.     SO2      NOX      NOX*1     NOX*2    HUM.     DEW     STAT
                  #/HR      F       PPM      PPM      PPM       PPM      #/#     POINT    PRES
                                                                                   F      IN.WG
FURNACE EXIT     5452.    680.0   1007.6   ******   ******     870.3    0.059   116.9     2.6
FLOAT.BED EX     3686.    138.0     10.3    124.8   ******     902.0    0.196   153.4   -16.3
NOX SCRUB IN     3508.    176.0     10.3    233.4   ******     686.0    0.196   153.4     2.7
NOX SCRUB EX     3554.    136.0      6.0    209.1   ******     635.2    0.212   157.4     0.0

NOX SCRUB.DATA TEMP.  FLOW     SCRUB.PERFORMANCE         SPRAY SLURRY ANALYSIS
                 F    #/MIN      SO2 ABSORB.    41.70
MAKEUP WATER    60.0   1.71      NOX ABSORP.    10.45       MGO,GM/100ML          2.850
MAKEUP MGO      60.0   0.76      NOX1 ABSORP   ******       MGSO3(SOLID),M      0.0094
PRODUCT LIQ.   138.0   3.10      NOX2 ABSORP     7.41       MGSO3(TOTAL),M      0.0097
RECIRC. LIQ.   138.0  1250.      GAS VEL.FPS     1.8        MGSO4,MOLAR         0.0075
                                 L/G,GAL/MCF   147.0        MG(NO2)2, MOLAR     0.0270
NO2 FLOW DATA                    L/G,#/#        21.4        MG(NO3)2, MOLAR     0.0023
  NO2 FLOWRATE,#/MIN     0.0     PRES.DROP,WG    0.1        TSS,GM/100ML        11.677
  NO2/NO( PDS BASIS)     0.87                               NITRITE/NITRATE  11.739
  NO2/NO(FC & ROTO)      0.0

MATERIAL BALANCE                                   **      MAKEUP MGO COMPOSITION
                    SULFUR  MAGNESIUM  WATER    NITROGEN      SLURRY CONC.,GM MGO/100ML=    0.0
 NOX SCRUBBER
  INPUT,#/HR         0.03     0.0      723.8     0.31
  OUTPUT,#/HR        0.12     3.39     624.3     0.43

PHYSICAL PROPERTIES OF
RECYCLED SLURRY

  PH                     9.30
  CONDUCT.MICROMHOS        0.
  SPECIFIC GRAVITY       0.0



NOX   = PDS ANALYSIS
NOX*1 = SALTSMAN ANALYSIS
NOX*2 = FUEL CELL ANALYSIS

** OXIDIZED NITROGEN ONLY
```

```
                               MAGNESIUM BASE SLURRY SCRUBBING PROGRAM-OUTPUT DATA PAGE 1

  RUN NUMBER  2-A          DATE 9-15-71     TIME OF DAY 1745

 FLUE GAS DATA            FLOW    TEMP.     SO2      SO3     NOX    FLYASH     HUM.     DEW      DRY      STAT
                          #/HR      F       PPM      PPM     PPM    GR/DSCF    #/#     POINT     FLOW     PRES
                                                                                         F       #/HR    IN.H2O
  PRIMARY AIR              487.    110.0   ------   -----   -----   -------   0.014    71.8      480.     13.5
  SECONDARY AIR           4523.    685.0   ------   -----   -----   -------   0.017    76.4     4449.      4.0
  FURNACE EXIT            5401.    640.0   1862.4   *****   *****   *******   0.058   116.3     5104.      0.0
  PART.SCRB.INLET         5401.    570.0   ******   *****   *****   *******   0.058   116.3     -----      2.7
  PART.CYC.EXIT           3494.    143.0   1720.0   *****   *****   *******   0.161   148.2     3010.     -6.8
  VENT ABS.INLET          *****   ******   ******   *****   *****   *******  ******   *****     -----    *****
  ABS CYC.EXIT            *****   ******   ******   *****   *****   *******  ******   *****     -----    *****
  FLOATING BED IN         3494.    143.0   ******   *****   *****   *******   0.161   148.2     -----     -6.8
  FLOATING BED EX         3847.      0.0   ******   *****   *****   *******   0.191   152.8     -----    -13.5
  P.P. EXIT ORIF.         3847.    135.0      3.5   *****    421.   *******   0.191   152.8     3230.    -13.5

 SCRUBBER STREAM DATA                                                VENTURI ABSORBER        FBA
  PARTICULATE              TEMP,F   FLOW,GPM        GAS ABSORBER     TEMP,F FLOW,#/M   TEMP,F  FLOW,#/M
   MAKEUP WATER             60.0      0.0            MAKEUP WATER     *****   *****      60.0      0.8
   PRODUCT LIQ.            142.0      0.0            MAKEUP MGO SL.   *****     3.2       0.0      3.2
   RECIRCULATED LIQ.       142.0     20.02           PRODUCT LIQ.     *****   *****     141.0      0.0
                                                     REC.(SPRAY NOZ)  *****   *****     141.0      0.0
                                                     REC.(FLOW NOZ.)          *****              380.0

 FURNACE PERFORMANCE                       SCRUBBER PERFORMANCE        PART.    VENT ABS.    FLOAT.BED
  HEAT RELEASE,BTU/HR    0.519E 07          SO2 ABSORB.EFF             7.65     ******         99.79
  %   FUEL AS COAL            96.2          FLYASH COL.EFF           ******     ******        ******
  COAL FLOW RATE,#/HR        410.3          SO3 ABSORB.EFF           ******     ******        ******
  NAT.GAS FLOW,#/HR            8.8          NOX ABSORB.EFF           ******     ******        ******
  %   EXCESS AIR              16.7          GAS VELOCITY,FPS           97.5     ******           6.6
  OXYGEN,%DRY,MEAS.           3.50          LIQ/GAS,GAL/MCF            20.7     ******          54.3
  CO2,%DRY-CALC.             15.03          LIQ/GAS,#/#                 2.9     ******           5.9
  HUMIDITY,#/# - CALC.       0.058          PRES.DROP,IN.WG             3.0     ******           4.6

SO2 ABSORPTION PARAMETERS                                                 SULFATE FORMATION PARAMETERS
 VENTURI ABSORBER                    FLOATING BED ABSORBER
                                                                          CONC.,GM-MOLE/L=  ******
  KGA,#MOLE/HR-FT3,     = ******      KGA,#MOLE/HR-FT3         =    41.4    MOL% TOTAL SULF=  *****
  SULFITE/SO2-MOL/MOL = ******      SULFITE/SO2-MOL/MOL      =   20.86    O2 AT FURN. EX.=   3.50
  SUMP RESID.TIME,MIN = ******      SUMP RESID.TIME,MIN      =  ******    O2 AT ABSORB.IN=  *****
                                                                          O2 AT ABSORB.EX=  *****
 ***** MEANS ITEM NOT MEASURED
```

```
                MAGNESIUM BASE SLURRY SCRUBBING PROGRAM - OUTPUT DATA PAGE 2

   RUN NUMBER  2-A          DATE 9-15-71     TIME OF DAY 1745

MATERIAL BALANCES                                                 INPUT FOR EQ. - KIN.PROG.
                   SULFUR   MAGNESIUM  FLYASH    WATER    DRY GAS
  FURNACE                                                         INPUT FLOWS,#ATOMS/100#FEED
    INPUT,#/HR      15.18    ------     30.36    278.1    5097.     CARBON      0.467256
    OUTPUT,#/HR      9.93    ------    ******    297.1    5104.     HYDROGEN    0.595881
                                                                    OXYGEN      1.394189
  PART.SCRUBBER                                                     NITROGEN    5.055843
    INPUT,#/HR       9.93    ------    ******     360.    5104.     SULFUR      0.008870
    OUTPUT,#/HR      5.41    ------    ******     484.    3010.
                                                                   FEED RATE,#/SEC=   1.49
  SO2 ABSORBERS
    INPUT,#/HR       5.41     7.72     ******     712.    3010.    ENTHALPY,BTU/# =   -4636.
    OUTPUT,#/HR      0.01    ******    ******     617.    3230.
 *
 *SO2 ABSORBERS-   GM SO2/   GM-MOLE/    GRAM/         MAKEUP MGO COMPOSITION
 PRODUCT COMP.     100ML     LITER       100ML          SLURRY CONC.- GM MGO/100ML =       6.70
                                                        MGO PRESLAKED, NO=0, YES=1            0
  TOTAL,            2.40     0.3755     ------          % SLAKED TO MG(OH)2,MEAS.  =    ******
  COMBINED          2.40     0.3755     ------
  FREE              0.0      0.0        ------         PRODUCT MG BASE PHYSICAL PROPERTIES
  MONO(TOTAL)       2.40     0.3755     ------          ACID STRENGTH, PH      =    8.10
  MONO(DISSOLVED)   1.06     0.1656      1.722          SP.GRAVITY,HYDROM.     =    1.0750
  MONO(SOLID)       1.34     0.2099      4.449
  BISULFITE         0.0      0.0         0.0
  MGO               4.56     0.7131      2.852
  SULFATE          *****     ******     ******         PARTICULATE SCRUBBER PRODUCT
  MAGNESIUM         6.97     1.0886     ------          ACID STRENGTH , PH       =   5.55
  FLYASH           -----     ------     ******          FLYASH CONC. GM/100ML    =   5.50
  SOLIDS.MG        -----     ------     20.411

  COAL COMPOSITION-MASS

    CARBON      0.7150
    HYDROGEN    0.0485
    OXY+NIT     0.0817
    SULFUR      0.0370
    ASH         0.0740
    WATER       0.0438

 *
 *SOLIDS FREE BASIS, MASS/VOLUME SOLUTION
```

B-6

```
RUN NUMBER  2-A           DATE 9-15-71      TIME OF DAY 1745

FLUE GAS DATA    FLOW     TEMP.      SO2       NOX      NOX*1     NOX*2     HUM.     DEW      STAT
                 #/HR      F         PPM       PPM      PPM       PPM       #/#      POINT    PRES
                                                                                     F       IN.WG
FURNACE EXIT     5401.    640.0    1862.4   ******    ******    485.8     0.058    116.3      0.0
FLOAT.BED EX     3847.    135.0       3.5    420.7    ******    485.8     0.191    152.8    -13.5
NOX SCRUB IN     3913.    136.0    ******   1122.1     876.9    803.4     0.191    152.8      1.4
NOX SCRUB EX     3924.    128.0    ******    901.3    ******    308.3     0.194    154.7      0.0

NOX SCRUB.DATA TEMP.  FLOW      SCRUB.PERFORMANCE        SPRAY SLURRY ANALYSIS
                F     #/MIN       SO2 ABSORB.   ******
MAKEUP WATER   60.0   0.81        NOX ABSORP.    19.67      MGO,GM/100ML          1.787
MAKEUP MGO     60.0   2.00        NOX1 ABSORP   ******      MGSO3(SOLID),M       0.0156
PRODUCT LIQ.  133.0   2.35        NOX2 ABSORP    61.63      MGSO3(TOTAL),M       0.0157
RECIRC. LIQ.  133.0  1250.        GAS VEL.FPS     1.9       MGSO4,MOLAR          0.0066
                                  L/G,GAL/MCF   140.5       MG(NO2)2, MOLAR      0.0055
NO2 FLOW DATA                     L/G,#/#        19.2       MG(NO3)2, MOLAR      0.0103
  NO2 FLOWRATE,#/MIN    0.09       RES.DROP,WG    0.0       TSS,GM/100ML        10.677
  NO2/NO( PDS BASIS)    1.67                                NITRITE/NITRATE      0.534
  NO2/NO(FC & ROTO)     2.29

MATERIAL BALANCE                                       **       MAKEUP MGO COMPOSITION
                        SULFUR  MAGNESIUM  WATER    NITROGEN        SLURRY CONC.,GM MGO/100ML=    0.0
  NOX SCRUBBER
   INPUT,#/HR            0.01     0.0      796.2      1.68
   OUTPUT,#/HR           0.10     1.64     640.5      1.42

PHYSICAL PROPERTIES OF
RECYCLED SLURRY

    PH                   7.90
    CONDUCT.MICROMHOS    5170.
    SPECIFIC GRAVITY     1.018



NOX   = PDS ANALYSIS
NOX*1 = SALTSMAN ANALYSIS
NOX*2 = FUEL CELL ANALYSIS

** OXIDIZED NITROGEN ONLY
```

```
                                   MAGNESIUM BASE SLURRY SCRUBBING PROGRAM-OUTPUT DATA PAGE 1

  RUN NUMBER  3-E          DATE 9-15-71     TIME OF DAY 2000

 FLUE GAS DATA             FLOW    TEMP.     SO2     SO3     NOX    FLYASH     HUM.    DEW      DRY      STAT
                           #/HR     F        PPM     PPM     PPM   GR/DSCF     #/#    POINT     FLOW     PRES
                                                                                        F       #/HR    IN.H2O
  PRIMARY AIR               487.   110.0   ------   -----   -----  -------    0.015    73.8     480.     13.5
  SECONDARY AIR            5128.   672.5   ------   -----   -----  -------    0.014    71.2    5057.      4.7
  FURNACE EXIT             6055.   650.0   1649.6   *****   *****  *******    0.056   114.9    5736.      0.0
  PART.SCRB.INLET          6055.   540.0   ******   *****   *****  *******    0.056   114.9    -----      2.7
  PART.CYC.EXIT            3397.   144.0   ******   *****   *****  *******    0.150   146.0    2954.     -6.8
  VENT ABS.INLET           *****  ******   ******   *****   *****  *******   ******   *****    -----    *****
  ABS CYC.EXIT             *****  ******   ******   *****   *****  *******   ******   *****    -----    *****
  FLOATING BED IN          3397.   146.0   ******   *****   *****  *******    0.150   146.0    -----     -6.8
  FLOATING BED EX          3761.     0.0   ******   *****   *****  *******    0.181   151.2    -----    -13.5
  P.P. EXIT ORIF.          3761.   136.0      9.4   *****   *****  *******    0.181   151.2    3185.    -13.5

 SCRUBBER STREAM DATA                                              VENTURI ABSORBER       FBA
  PARTICULATE             TEMP,F   FLOW,GPM         GAS ABSORBER   TEMP,F FLOW,#/M   TEMP,F  FLOW,#/M
   MAKEUP WATER            60.0      0.0             MAKEUP WATER   *****    *****      60.0      0.8
   PRODUCT LIQ.           143.0      0.0             MAKEUP MGO SL. *****      2.9       0.0      2.8
   RECIRCULATED LIQ.      143.0     20.02            PRODUCT LIQ.   *****    *****     140.0      0.0
                                                     REC.(SPRAY NOZ) *****   *****     140.0      0.0
                                                     REC.(FLOW NOZ.)         *****              380.0

 FURNACE PERFORMANCE                        SCRUBBER PERFORMANCE      PART.     VENT ABS.    FLOAT.BED
  HEAT RELEASE,BTU/HR     0.583E 07          SO2 ABSORB.EFF          ******      ******       ******
  %   FUEL AS COAL            96.6           FLYASH COL.EFF          ******      ******       ******
  COAL FLOW RATE,#/HR        462.8           SO3 ABSORB.EFF          ******      ******       ******
  NAT.GAS FLOW,#/HR            8.8           NOX ABSORB.EFF          ******      ******       ******
  %   EXCESS AIR              16.7           GAS VELOCITY,FPS          94.4      ******          6.4
  OXYGEN,%DRY,MEAS.           3.50           LIQ/GAS,GAL/MCF           21.4      ******         55.9
  CO2,%DRY-CALC.             15.05           LIQ/GAS,#/#                2.9      ******          6.1
  HUMIDITY,#/# - CALC.       0.056           PRES.DROP,IN.WG            3.0      ******          5.5

SO2 ABSORPTION PARAMETERS                                                SULFATE FORMATION PARAMETERS
 VENTURI ABSORBER                      FLOATING BED ABSORBER
                                                                          CONC.,GM-MOLE/L=   ******
  KGA,#MOLE/HR-FT3,      = ******       KGA,#MOLE/HR-FT3        =  ******   MOL% TOTAL SULF=   *****
  SULFITE/SO2-MOL/MOL    = ******       SULFITE/SO2-MOL/MOL     =  ******   O2 AT FURN. EX.=   3.50
  SUMP RESID.TIME,MIN    = ******       SUMP RESID.TIME,MIN     =  ******   O2 AT ABSORB.IN=   *****
                                                                          O2 AT ABSORB.EX=   *****

  ***** MEANS ITEM NOT MEASURED
```

B-8

```
                     MAGNESIUM BASE SLURRY SCRUBBING PROGRAM - OUTPUT DATA PAGE 2

   RUN NUMBER  3-E            DATE 9-15-71      TIME OF DAY 2000

 MATERIAL BALANCES                                                         INPUT FOR EQ. - KIN.PROG.
                      SULFUR     MAGNESIUM   FLYASH     WATER    DRY GAS
   FURNACE                                                                 INPUT FLOWS,#ATOMS/100#FEED
     INPUT,#/HR        17.12       ------     34.24     300.3     5726.      CARBON      0.467918
     OUTPUT,#/HR        9.88       ------    ******     319.3     5736.      HYDROGEN    0.693335
                                                                             OXYGEN      1.394246
   PART.SCRUBBER                                                             NITROGEN    5.055199
     INPUT,#/HR         9.88       ------    ******     382.      5736.      SULFUR      0.008905
     OUTPUT,#/HR      ******       ------    ******     442.      2954.
                                                                            FEED RATE,#/SEC=    1.67
   SO2 ABSORBERS
     INPUT,#/HR       ******         6.25    ******     649.      2954.     ENTHALPY,BTU/# =    -3592.
     OUTPUT,#/HR        0.03       ******    ******     577.      3185.
 *
 *SO2 ABSORBERS-      GM SO2/     GM-MOLE/     GRAM/           MAKEUP MGO COMPOSITION
  PRODUCT COMP.       100ML       LITER        100ML            SLURRY CONC.- GM MGO/100ML =       6.20
                                                                MGO PRESLAKED, NO=0, YES=1          0
   TOTAL,              3.13       0.4892      ------            % SLAKED TO MG(OH)2,MEAS.  =    ******
   COMBINED            3.13       0.4892      ------
   FREE                0.0        0.0         ------           PRODUCT MG BASE PHYSICAL PROPERTIES
   MONO(TOTAL)         3.13       0.4892      ------            ACID STRENGTH, PH       =    8.05
   MONO(DISSOLVED)     1.18       0.1844       1.917            SP.GRAVITY,HYDROM.      =    1.0780
   MONO(SOLID)         1.95       0.3049       6.463
   BISULFITE           0.0        0.0          0.0
   MGO                 4.28       0.6695       2.678
   SULFATE            *****      ******      ******            PARTICULATE SCRUBBER PRODUCT
   MAGNESIUM           7.42       1.1587      ------            ACID STRENGTH , PH       =   5.50
   FLYASH             -----      ------      ******             FLYASH CONC. GM/100ML    =  *****
   SOLIDS,MG          -----      ------      19.612

  COAL COMPOSITION-MASS

    CARBON      0.7150
    HYDROGEN    0.0485
    OXY+NIT     0.0817
    SULFUR      0.0370
    ASH         0.0740
    WATER       0.0438

 *
 *SOLIDS FREE BASIS, MASS/VOLUME SOLUTION
```

```
RUN NUMBER  3-E          DATE 9-15-71     TIME OF DAY 2000

FLUE GAS DATA    FLOW    TEMP.    SO2     NOX      NOX*1    NOX*2    HUM.    DEW     STAT
                 #/HR    F        PPM     PPM      PPM      PPM      #/#     POINT   PRES
                                                                             F       IN.WG
FURNACE EXIT     6055.   650.0   1649.6  ******   ******    485.6   0.056   114.9     0.0
FLOAT.BED EX     3761.   136.0      9.4  ******   ******    504.3   0.181   151.2   -13.5
NOX SCRUB IN     3748.   162.0   ******   969.3    930.3    644.4   0.181   151.2     1.4
NOX SCRUB EX     3781.   130.0   ******  1180.9    986.7    551.0   0.192   154.3     0.0

NOX SCRUB.DATA TEMP. FLOW      SCRUB.PERFORMANCE          SPRAY SLURRY ANALYSIS
                F    #/MIN      SO2 ABSORB.    ******
MAKEUP WATER   60.0   0.81      NOX ABSORP.   -21.83       MGO,GM/100ML          1.462
MAKEUP MGO     60.0   2.00      NOX1 ABSORP    -6.07       MGSO3(SOLID),M      0.0
PRODUCT LIQ.  134.0   2.35      NOX2 ABSORP    14.49       MGSO3(TOTAL),M      0.0
RECIRC. LIQ.  134.0   850.      GAS VEL.FPS     1.8        MGSO4,MOLAR         0.0047
                                L/G,GAL/MCF    96.1        MG(NO2)2, MOLAR     0.0155
NO2 FLOW DATA                   L/G,#/#        13.6        MG(NO3)2, MOLAR     0.0095
  NO2 FLOWRATE,#/MIN   0.09     PRES.DROP,WG    0.0        TSS,GM/100ML          8.398
  NO2/NO( PDS BASIS)   *****                               NITRITE/NITRATE     1.632
  NO2/NO(FC & ROTO)    2.24

MATERIAL BALANCE                                      **      MAKEUP MGO COMPOSITION
                     SULFUR  MAGNESIUM  WATER    NITROGEN       SLURRY CONC.,GM MGO/100ML=   4.00
  NOX SCRUBBER
   INPUT,#/HR         0.03     2.88     738.5     1.40
   OUTPUT,#/HR        0.02     1.34     610.2     1.81

PHYSICAL PROPERTIES OF
RECYCLED SLURRY

   PH                   8.05
   CONDUCT.MICROMHOS       0.
   SPECIFIC GRAVITY      1.018


NOX   = PDS ANALYSIS
NOX*1 = SALTSMAN ANALYSIS
NOX*2 = FUEL CELL ANALYSIS

** OXIDIZED NITROGEN ONLY
```

```
                          MAGNESIUM BASE SLURRY SCRUBBING PROGRAM-OUTPUT DATA PAGE 1

  RUN NUMBER  4-F          DATE 9-16-71     TIME OF DAY 1200

 FLUE GAS DATA             FLOW    TEMP.     SO2     SO3     NOX   FLYASH     HUM.    DEW     DRY      STAT
                           #/HR      F       PPM     PPM     PPM   GR/DSCF    #/#    POINT   FLOW      PRES
                                                                                       F     #/HR     IN.H2O
  PRIMARY AIR              462.    110.0  ------   -----   -----  -------    0.012   65.6    456.    -14.9
  SECONDARY AIR           4454.    685.0  ------   -----   -----  -------    0.010   60.6   4408.      5.0
  FURNACE EXIT            5294.    540.0  1538.4   *****   *****  *******    0.052  112.8   5033.      0.0
  PART.SCRB.INLET         5294.    450.0  ******   *****   *****  *******    0.052  112.8   -----      2.7
  PART.CYC.EXIT           3323.    142.0  1431.0   *****   *****  *******    0.125  140.6   2954.     -6.8
  VENT ABS.INLET         *****   ******  ******   *****   *****  *******   ******  *****   -----    *****
  ABS CYC.EXIT           *****   ******  ******   *****   *****  *******   ******  *****   -----    *****
  FLOATING BED IN         3323.    143.0  ******   *****   *****  *******    0.125  140.6   -----     -6.8
  FLOATING BED EX         3604.      0.0  ******   *****   *****  *******    0.156  146.4   -----    -17.6
  P.P. EXIT ORIF.         3604.    128.0    10.3   *****    502.  *******    0.156  146.4   3118.    -17.6

 SCRUBBER STREAM DATA                                            VENTURI ABSORBER        FBA
  PARTICULATE             TEMP,F   FLOW,GPM      GAS ABSORBER    TEMP,F FLOW,#/M   TEMP,F  FLOW,#/M
   MAKEUP WATER            60.0      0.0          MAKEUP WATER    *****    *****      60.0      0.6
   PRODUCT LIQ.           135.0      0.0          MAKEUP MGO SL.  *****      3.2       0.0      3.2
   RECIRCULATED LIQ.      135.0     20.02         PRODUCT LIQ.    *****    *****     133.0      0.0
                                                  REC.(SPRAY NOZ) *****    *****     133.0    380.0
                                                  REC.(FLOW NOZ.)          *****              380.0

 FURNACE PERFORMANCE                      SCRUBBER PERFORMANCE      PART.     VENT ABS.     FLOAT.BED
  HEAT RELEASE,BTU/HR     0.504E 07        SO2 ABSORB.EFF           6.98       ******         99.28
  %   FUEL AS COAL             96.1        FLYASH COL.EFF         ******       ******        ******
  COAL FLOW RATE,#/HR         397.5        SO3 ABSORB.EFF         ******       ******        ******
  NAT.GAS FLOW,#/HR             8.9        NOX ABSORB.EFF         ******       ******        ******
  %   EXCESS AIR               18.1        GAS VELOCITY,FPS         90.4       ******           6.1
  OXYGEN,%DRY,MEAS.            3.80        LIQ/GAS,GAL/MCF          22.3       ******          58.7
  CO2,%DRY-CALC.              14.77        LIQ/GAS,#/#               3.0       ******           6.3
  HUMIDITY,#/# - CALC.        0.052        PRES.DROP,IN.WG           2.3       ******          12.8

SO2 ABSORPTION PARAMETERS                                            SULFATE FORMATION PARAMETERS
  VENTURI ABSORBER               FLOATING BED ABSORBER
                                                                      CONC.,GM-MOLE/L=  ******
  KGA,#MOLE/HR-FT3,      = ******   KGA,#MOLE/HR-FT3         =   31.9   MOL% TOTAL SULF=  *****
  SULFITE/SO2-MOL/MOL = ******   SULFITE/SO2-MOL/MOL      = ******   O2 AT FURN. EX.=   3.80
  SUMP RESID.TIME,MIN = ******   SUMP RESID.TIME,MIN      = ******   O2 AT ABSORB.IN=  *****
                                                                      O2 AT ABSORB.EX=  *****
  ***** MEANS ITEM NOT MEASURED
```

```
               MAGNESIUM BASE SLURRY SCRUBBING PROGRAM - OUTPUT DATA PAGE 2

  RUN NUMBER  4-F          DATE 9-16-71      TIME OF DAY 1200

MATERIAL BALANCES                                                    INPUT FOR EQ. - KIN.PROG.
                     SULFUR   MAGNESIUM  FLYASH    WATER    DRY GAS
  FURNACE                                                            INPUT FLOWS,#ATOMS/100#FEED
    INPUT,#/HR        14.71    ------     29.42    242.5     5026.     CARBON        0.459826
    OUTPUT,#/HR        8.09    ------    ******    261.6     5033.     HYDROGEN      0.570051
                                                                       OXYGEN        1.395035
  PART.SCRUBBER                                                        NITROGEN      5.062690
    INPUT,#/HR         8.09    ------    ******     324.     5033.     SULFUR        0.008723
    OUTPUT,#/HR        4.42    ------    ******     370.     2954.
                                                                      FEED RATE,#/SEC=   1.46
  SO2 ABSORBERS
    INPUT,#/HR         4.42      7.14    ******     586.     2954.    ENTHALPY,BTU/# =   -1477.
    OUTPUT,#/HR        0.03    ******    ******     486.     3118.
*
*SO2 ABSORBERS-      GM SO2/   GM-MOLE/     GRAM/        MAKEUP MGO COMPOSITION
 PRODUCT COMP.       100ML     LITER        100ML         SLURRY CONC.- GM MGO/100ML =       6.20
                                                          MGO PRESLAKED, NO=0, YES=1          0
  TOTAL,               1.45    0.2263       ------        % SLAKED TO MG(OH)2,MEAS.  =    ******
  COMBINED             1.45    0.2263       ------
  FREE                 0.0     0.0          ------       PRODUCT MG BASE PHYSICAL PROPERTIES
  MONO(TOTAL)          1.45    0.2263       ------        ACID STRENGTH, PH      =     7.80
  MONO(DISSOLVED)    *****     ******       ******        SP.GRAVITY,HYDROM.     =     1.0200
  MONO(SOLID)        *****     ******       ******
  BISULFITE          *****     ******       ******
  MGO                  1.71    0.2672        1.069
  SULFATE            *****     ******       ******       PARTICULATE SCRUBBER PRODUCT
  MAGNESIUM            3.16    0.4934       ------        ACID STRENGTH , PH      =   6.10
  FLYASH             -----     ------       ******        FLYASH CONC. GM/100ML  =  *****
  SOLIDS,MG          -----     ------        1.690

 COAL COMPOSITION-MASS

   CARBON      0.7150
   HYDROGEN    0.0485
   OXY+NIT     0.0817
   SULFUR      0.0370
   ASH         0.0740
   WATER       0.0438

*
*SOLIDS FREE BASIS, MASS/VOLUME SOLUTION
```

```
RUN NUMBER  4-F            DATE 9-16-71     TIME OF DAY 1200

FLUE GAS DATA    FLOW    TEMP.    SO2      NOX      NOX*1    NOX*2    HUM.    DEW      STAT
                 #/HR     F       PPM      PPM      PPM      PPM      #/#     POINT    PRES
                                                                               F       IN.WG
FURNACE EXIT     5294.   540.0   1538.4   ******   ******   561.9    0.052   112.8      0.0
FLOAT.BED EX     3604.   128.0     10.3    502.4   ******   486.9    0.156   146.4    -17.6
NOX SCRUB IN     3541.   160.0   ******    759.5    613.9   580.6    0.156   146.4      1.4
NOX SCRUB EX     3581.   122.0   ******    855.0    751.1   299.7    0.169   150.7      0.0

NOX SCRUB.DATA TEMP. FLOW     SCRUB.PERFORMANCE          SPRAY SLURRY ANALYSIS
                F    #/MIN     SO2 ABSORB.   ******
MAKEUP WATER   60.0   0.71     NOX ABSORP.   -12.57      MGO,GM/100ML          3.031
MAKEUP MGO     60.0   2.00     NOX1 ABSORP   -22.35      MGSO3(SOLID),M        0.0
PRODUCT LIQ.  124.0   2.95     NOX2 ABSORP    48.39      MGSO3(TOTAL),M        0.0008
RECIRC. LIQ.  124.0   500.     GAS VEL.FPS     1.7       MGSO4,MOLAR           0.0076
                               L/G,GAL/MCF    61.0       MG(NO2)2, MOLAR       0.0054
NO2 FLOW DATA                  L/G,#/#         8.5       MG(NO3)2, MOLAR       0.0014
  NO2 FLOWRATE,#/MIN    0.06   PRES.DROP,WG    0.0       TSS,GM/100ML          7.519
  NO2/NO( PDS BASIS)    0.51                             NITRITE/NITRATE       3.857
  NO2/NO(FC & ROTO)     1.55

MATERIAL BALANCE                                  **      MAKEUP MGO COMPOSITION
                     SULFUR  MAGNESIUM  WATER   NITROGEN     SLURRY CONC.,GM MGO/100ML=    4.00
 NOX SCRUBBER
  INPUT,#/HR          0.03     2.88     635.5     1.06
  OUTPUT,#/HR         0.05     3.28     520.3     1.23

PHYSICAL PROPERTIES OF
RECYCLED SLURRY

   PH                    9.20
   CONDUCT.MICROMHOS     2280.
   SPECIFIC GRAVITY      1.015


NOX   = PDS ANALYSIS
NOX*1 = SALTSMAN ANALYSIS
NOX*2 = FUEL CELL ANALYSIS

** OXIDIZED NITROGEN ONLY
```

```
                                MAGNESIUM BASE SLURRY SCRUBBING PROGRAM-OUTPUT DATA PAGE 1

  RUN NUMBER  5-K           DATE 9-16-71      TIME OF DAY 1530

 FLUE GAS DATA              FLOW    TEMP.     SO2     SO3     NOX    FLYASH     HUM.    DEW      DRY      STAT
                            #/HR     F        PPM     PPM     PPM    GR/DSCF    #/#    POINT    FLOW      PRES
                                                                                         F      #/HR     IN.H2O
  PRIMARY AIR                487.   115.0   ------   -----   -----   -------   0.015   74.2     480.     14.9
  SECONDARY AIR             5146.   687.5   ------   -----   -----   -------   0.011   64.9    5089.      5.3
  FURNACE EXIT              6073.   600.0   ******   *****   *****   *******   0.053  113.5    5767.      0.0
  PART.SCRB.INLET           6073.   510.0   ******   *****   *****   *******   0.053  113.5    -----      1.4
  PART.CYC.EXIT             3188.   142.0   ******   *****   *****   *******   0.140  143.7    2797.     -9.5
  VENT ABS.INLET            *****  ******   ******   *****   *****   *******  ******  *****    -----    *****
  ABS CYC.EXIT              *****  ******   ******   *****   *****   *******  ******  *****    -----    *****
  FLOATING BED IN           3188.   140.0   ******   *****   *****   *******   0.140  143.7    -----    -10.8
  FLOATING BED EX           3409.     0.0   ******   *****   *****   *******   0.173  150.1    -----    -12.2
  P.P. EXIT ORIF.           3409.   128.0   ******   *****    589.   *******   0.173  150.1    2907.    -12.2

 SCRUBBER STREAM DATA                                                VENTURI ABSORBER          FBA
  PARTICULATE               TEMP,F    FLOW,GPM       GAS ABSORBER    TEMP,F  FLOW,#/M    TEMP,F   FLOW,#/M
   MAKEUP WATER              60.0       0.0           MAKEUP WATER    *****    *****       60.0      0.0
   PRODUCT LIQ.             132.0       0.0           MAKEUP MGO SL.  *****      2.8       80.0      2.8
   RECIRCULATED LIQ.        132.0      20.02          PRODUCT LIQ.    *****    *****      132.0      0.0
                                                      REC.(SPRAY NOZ) *****    *****      132.0      0.0
                                                      REC.(FLOW NOZ.)          *****               367.0

 FURNACE PERFORMANCE                          SCRUBBER PERFORMANCE        PART.     VENT ABS.    FLOAT.BED
  HEAT RELEASE,BTU/HR     0.583E 07             SO2 ABSORB.EFF           ******     ******       ******
  %   FUEL AS COAL             96.6             FLYASH COL.EFF           ******     ******       ******
  COAL FLOW RATE,#/HR         462.7             SO3 ABSORB.EFF           ******     ******       ******
  NAT.GAS FLOW,#/HR             8.9             NOX ABSORB.EFF           ******     ******       ******
  %   EXCESS AIR               17.1             GAS VELOCITY,FPS           88.0     ******          5.7
  OXYGEN,%DRY,MEAS.            3.60             LIQ/GAS,GAL/MCF            22.9     ******         60.3
  CO2,%DRY-CALC.              14.96             LIQ/GAS,#/#                 3.1     ******          6.5
  HUMIDITY,#/# - CALC.        0.053             PRES.DROP,IN.WG             4.5     ******          5.5

SO2 ABSORPTION PARAMETERS                                                  SULFATE FORMATION PARAMETERS
  VENTURI ABSORBER                        FLOATING BED ABSORBER

                                                                             CONC.,GM-MOLE/L=   ******
  KGA,#MOLE/HR-FT3,      = ******      KGA,#MOLE/HR-FT3        =  ******     MOL% TOTAL SULF=   *****
  SULFITE/SO2-MOL/MOL    = ******      SULFITE/SO2-MOL/MOL     =  ******     O2 AT FURN. EX.=    3.60
  SUMP RESID.TIME,MIN    = ******      SUMP RESID.TIME,MIN     =  ******     O2 AT ABSORB.IN=   *****
                                                                             O2 AT ABSORB.EX=   *****
  ***** MEANS ITEM NOT MEASURED
```

```
                  MAGNESIUM BASE SLURRY SCRUBBING PROGRAM - OUTPUT DATA PAGE 2

   RUN NUMBER  5-K          DATE 9-16-71     TIME OF DAY 1530

MATERIAL BALANCES                                                        INPUT FOR EQ. - KIN.PROG.
                     SULFUR    MAGNESIUM   FLYASH    WATER    DRY GAS
  FURNACE                                                                INPUT FLOWS,#ATOMS/100#FEED
    INPUT,#/HR        17.12     ------      34.24     286.7     5758.      CARBON      0.465489
    OUTPUT,#/HR      ******     ------     ******     305.8     5767.      HYDROGEN    0.601821
                                                                           OXYGEN      1.394532
  PART.SCRUBBER                                                            NITROGEN    5.057435
    INPUT,#/HR       ******     ------     ******     306.      5767.      SULFUR      0.008858
    OUTPUT,#/HR      ******     ------     ******     391.      2797.
                                                                          FEED RATE,#/SEC=   1.68
  SO2 ABSORBERS
    INPUT,#/HR       ******      6.25      ******     548.      2797.     ENTHALPY,BTU/# =   -1896.
    OUTPUT,#/HR      ******     ******     ******     502.      2907.
*
*SO2 ABSORBERS-      GM SO2/   GM-MOLE/     GRAM/           MAKEUP MGO COMPOSITION
 PRODUCT COMP.       100ML     LITER        100ML            SLURRY CONC.- GM MGO/100ML =       6.20
                                                             MGO PRESLAKED, NO=0, YES=1           0
  TOTAL,              1.50      0.2350     ------            % SLAKED TO MG(OH)2,MEAS.  =     ******
  COMBINED            1.50      0.2350     ------
  FREE                0.0       0.0        ------          PRODUCT MG BASE PHYSICAL PROPERTIES
  MONO(TOTAL)         1.50      0.2350     ------            ACID STRENGTH, PH      =     7.85
  MONO(DISSOLVED)     1.08      0.1687      1.755            SP.GRAVITY,HYDROM.     =     1.0200
  MONO(SOLID)         0.42      0.0663      1.405
  BISULFITE           0.0       0.0         0.0
  MGO                 1.10      0.1715      0.686
  SULFATE            *****     ******      ******          PARTICULATE SCRUBBER PRODUCT
  MAGNESIUM           2.60      0.4065     ------            ACID STRENGTH , PH       =   5.55
  FLYASH             -----     ------      ******            FLYASH CONC. GM/100ML  =  *****
  SOLIDS,MG          -----     ------       3.442

  COAL COMPOSITION-MASS

    CARBON      0.7150
    HYDROGEN    0.0485
    OXY+NIT     0.0817
    SULFUR      0.0370
    ASH         0.0740
    WATER       0.0438

*
*SOLIDS FREE BASIS, MASS/VOLUME SOLUTION
```

```
RUN NUMBER  5-K          DATE 9-16-71     TIME OF DAY 1530

FLUE GAS DATA    FLOW    TEMP.     SO2      NOX      NOX*1    NOX*2    HUM.    DEW     STAT
                 #/HR     F        PPM      PPM      PPM      PPM      #/#    POINT    PRES
                                                                                F     IN.WG
FURNACE EXIT    6073.    600.0   ******   ******   ******    588.1    0.053   113.5     0.0
FLOAT.BED EX    3409.    128.0   ******    589.4   ******    559.6    0.173   150.1   -12.2
NOX SCRUB IN    3260.    162.0   ******    671.3    901.6    777.8    0.173   150.1     1.4
NOX SCRUB EX    3291.    128.0   ******    920.6   1226.1    398.4    0.184   153.2     0.0

NOX SCRUB.DATA TEMP. FLOW     SCRUB.PERFORMANCE       SPRAY SLURRY ANALYSIS
                 F    #/MIN     SO2 ABSORB.   ******
MAKEUP WATER    60.0   0.48     NOX ABSORP.   -37.13     MGO,GM/100ML          1.662
MAKEUP MGO      60.0   1.20     NOX1 ABSORP   -35.99     MGSO3(SOLID),M       0.0125
PRODUCT LIQ.  132.0   1.70      NOX2 ABSORP    48.78     MGSO3(TOTAL),M       0.0133
RECIRC. LIQ.  132.0   680.      GAS VEL.FPS     1.6      MGSO4,MOLAR          0.0048
                                L/G,GAL/MCF    89.2      MG(NO2)2, MOLAR      0.0060
NO2 FLOW DATA                   L/G,#/#        12.5      MG(NO3)2, MOLAR      0.0010
  NO2 FLOWRATE,#/MIN     0.06   PRES.DROP,WG    0.1      TSS,GM/100ML        16.373
  NO2/NO( PDS BASIS)     0.14                            NITRITE/NITRATE      6.000
  NO2/NO(FC & ROTO)      1.45

MATERIAL BALANCE                                 **       MAKEUP MGO COMPOSITION
                   SULFUR  MAGNESIUM  WATER   NITROGEN       SLURRY CONC.,GM MGO/100ML=    4.00
  NOX SCRUBBER
   INPUT,#/HR      *****      1.73     578.3     0.85
   OUTPUT,#/HR      0.06      1.08     512.3     1.19

 PHYSICAL PROPERTIES OF
 RECYCLED SLURRY

   PH                    7.90
   CONDUCT.MICROMHOS     3600.
   SPECIFIC GRAVITY      1.018



 NOX   = PDS ANALYSIS
 NOX*1 = SALTSMAN ANALYSIS
 NOX*2 = FUEL CELL ANALYSIS

 ** OXIDIZED NITROGEN ONLY

IHC210I PROGRAM INTERRUPT(P) OLD PSW IS    FF15000 F 82015C58

'C210I PROGRAM INTERRUPT(P) OLD PSW IS    FF15000 F 82015C68
```

```
                                     MAGNESIUM BASE SLURRY SCRUBBING PROGRAM-OUTPUT DATA PAGE 1

  RUN NUMBER  6-L            DATE 9-22-71     TIME OF DAY 1545

  FLUE GAS DATA               FLOW    TEMP.     SO2      SO3      NOX    FLYASH     HUM.    DEW      DRY      STAT
                              #/HR      F       PPM      PPM      PPM    GR/DSCF    #/#     POINT    FLOW     PRES
                                                                                             F       #/HR    IN.H2O
   PRIMARY AIR                491.    110.0   ------   -----    -----   -------   0.010    61.2      486.    13.5
   SECONDARY AIR             5027.    708.8   ------   -----    -----   -------   0.015    74.3     4951.     4.8
   FURNACE EXIT              5947.    480.0   ******   *****    *****   *******   0.056   115.6     5630.     0.0
   PART.SCRB.INLET           5947.    410.0   ******   *****    *****   *******   0.056   115.6     -----     2.7
   PART.CYC.EXIT             3721.    134.0   ******   *****    *****   *******   0.122   139.8     3316.    -8.1
   VENT ABS.INLET            *****   ******   ******   *****    *****   *******  ******   *****     -----   *****
   ABS CYC.EXIT              *****   ******   ******   *****    *****   *******  ******   *****     -----   *****
   FLOATING BED IN           3721.    136.0   ******   *****    *****   *******   0.122   139.8     -----    -8.1
   FLOATING BED EX           4124.      0.0   ******   *****    *****   *******   0.151   148.7     -----    13.5
   P.P. EXIT ORIF.           4124.    125.0   1308.8   *****    *****   *******   0.151   148.7     3582.    13.5

  SCRUBBER STREAM DATA                                                     VENTURI ABSORBER        FBA
   PARTICULATE                TEMP,F    FLOW,GPM        GAS ABSORBER     TEMP,F FLOW,#/M   TEMP,F  FLOW,#/M
    MAKEUP WATER               60.0       0.0            MAKEUP WATER     *****    *****     60.0      1.0
    PRODUCT LIQ.              136.0       0.0            MAKEUP MGO SL.   *****      3.2      0.0      3.2
    RECIRCULATED LIQ.         136.0      20.02           PRODUCT LIQ.     *****    *****    132.0      0.0
                                                         REC.(SPRAY NOZ)  *****    *****    132.0      0.0
                                                         REC.(FLOW NOZ.)           *****             380.0

  FURNACE PERFORMANCE                           SCRUBBER PERFORMANCE          PART.      VENT ABS.     FLOAT.BED
   HEAT RELEASE,BTU/HR        0.569E 07          SO2 ABSORB.EFF              ******      ******        ******
   %   FUEL AS COAL                96.5         FLYASH COL.EFF               ******      ******        ******
   COAL FLOW RATE,#/HR            451.4          SO3 ABSORB.EFF              ******      ******        ******
   NAT.GAS FLOW,#/HR                8.9          NOX ABSORB.EFF              ******      ******        ******
   %   EXCESS AIR                  17.[illegible]         GAS VELOCITY,FPS              99.6      ******           6.4
   OXYGEN,%DRY,MEAS.               3.60         LIQ/GAS,GAL/MCF               20.3      ******          55.9
   CO2,%DRY-CALC.                 14.96         LIQ/GAS,#/#                    2.7      ******           5.5
   HUMIDITY,#/# - CALC.           0.056         PRES.DROP,IN.WG                3.3      ******           3.3

 SO2 ABSORPTION PARAMETERS                                                    SULFATE FORMATION PARAMETERS
   VENTURI ABSORBER                        FLOATING BED ABSORBER

   KGA,#MOLE/HR-FT3,     = ******        KGA,#MOLE/HR-FT3        =   ******     CONC.,GM-MOLE/L=   ******
   SULFITE/SO2-MOL/MOL  = ******         SULFITE/SO2-MOL/MOL     =   ******     MOL% TOTAL SULF=   *****
   SUMP RESID.TIME,MIN  = ******         SUMP RESID.TIME,MIN     =   ******     O2 AT FURN. EX.=    3.60
                                                                                O2 AT ABSORB.IN=   *****
  ***** MEANS ITEM NOT MEASURED                                                 O2 AT ABSORB.EX=   *****
```

```
                    MAGNESIUM BASE SLURRY SCRUBBING PROGRAM - OUTPUT DATA PAGE 2

   RUN NUMBER  6-L           DATE 9-22-71      TIME OF DAY 1545

MATERIAL BALANCES                                                        INPUT FOR EQ. - KIN.PROG.
                      SULFUR    MAGNESIUM  FLYASH     WATER     DRY GAS
  FURNACE                                                                INPUT FLOWS,#ATOMS/100#FEED
    INPUT,#/HR         16.70     ------     33.40     297.6      5622.     CARBON       0.465347
    OUTPUT,#/HR       ******     ------    ******     316.8      5630.     HYDROGEN     0.545518
                                                                           OXYGEN       1.394520
  PART.SCRUBBER                                                            NITROGEN     5.057571
    INPUT,#/HR        ******     ------    ******      379.      5630.     SULFUR       0.008351
    OUTPUT,#/HR       ******     ------    ******      405.      3316.
                                                                          FEED RATE,#/SEC=    1.64
  SO2 ABSORBERS
    INPUT,#/HR        ******     ******    ******      660.      3316.    ENTHALPY,BTU/# =    -3087.
    OUTPUT,#/HR       ******     ******    ******      541.      3582.
*
*SO2 ABSORBERS-       GM SO2/    GM-MOLE/     GRAM/         MAKEUP MGO COMPOSITION
 PRODUCT COMP.        100ML      LITER        100ML          SLURRY CONC.- GM MGO/100ML =     ******
                                                             MGO PRESLAKED, NO=0, YES=1            0
  TOTAL,              *****      ******      ------          % SLAKED TO MG(OH)2,MEAS.  =     ******
  COMBINED            *****      ******      ------
  FREE                *****      ******      ------         PRODUCT MG BASE PHYSICAL PROPERTIES
  MONO(TOTAL)         *****      ******      ------          ACID STRENGTH, PH      =   *****
  MONO(DISSOLVED)     *****      ******      ******          SP.GRAVITY,HYDROM.     =   *******
  MONO(SOLID)         *****      ******      ******
  BISULFITE           *****      ******      ******
  MGO                 *****      ******      ******
  SULFATE             *****      ******      ******         PARTICULATE SCRUBBER PRODUCT
  MAGNESIUM           *****      ******      ------          ACID STRENGTH , PH      =  *****
  FLYASH              -----      ------      ******          FLYASH CONC. GM/100ML   =  *****
  SOLIDS,MG           -----      ------      ******

  COAL COMPOSITION-MASS

    CARBON      0.7150
    HYDROGEN    0.0485
    OXY+NIT     0.0817
    SULFUR      0.0370
    ASH         0.0740
    WATER       0.0438

*
```

B-18

```
RUN NUMBER  6-L           DATE 9-22-71      TIME OF DAY 1545

FLUE GAS DATA     FLOW     TEMP.      SO2      NOX      NOX*1     NOX*2     HUM.      DEW      STAT
                  #/HR      F         PPM      PPM      PPM       PPM       #/#      POINT     PRES
                                                                                     F       IN.WG
FURNACE EXIT     5947.     480.0    ******   ******   ******    ******    0.056    115.6      0.0
FLOAT.BED EX     4124.     125.0    1308.8   ******   ******    ******    0.151    148.7     13.5
NOX SCRUB IN     3927.     164.0    1308.8   ******   ******    ******    0.151    148.7      1.4
NOX SCRUB EX     3980.     120.0      22.8   ******   ******    ******    0.167    150.4      0.0

NOX SCRUB.DATA TEMP.  FLOW     SCRUB.PERFORMANCE         SPRAY SLURRY ANALYSIS
                 F    #/MIN      SO2 ABSORB.     98.26
MAKEUP WATER    60.0   0.48      NOX ABSORP.    -37.13      MGO,GM/100ML        -0.0
MAKEUP MGO      60.0   3.40      NOX1 ABSORP    -35.99      MGSO3(SOLID),M       0.0
PRODUCT LIQ.   124.0   4.25      NOX2 ABSORP     48.78      MGSO3(TOTAL),M       0.0
RECIRC. LIQ.   124.0  1250.      GAS VEL.FPS      1.9       MGSO4,MOLAR          0.0
                                 L/G,GAL/MCF    137.7       MG(NO2)2, MOLAR      0.0
NO2 FLOW DATA                    L/G,#/#         19.1       MG(NO3)2, MOLAR      0.0
  NO2 FLOWRATE,#/MIN    0.0      PRES.DROP,WG     0.1       TSS,GM/100ML          0.0
  NO2/NO( PDS BASIS)   *****                                NITRITE/NITRATE      0.0
  NO2/NO(FC & ROTO)    *****

MATERIAL BALANCE                                   **       MAKEUP MGO COMPOSITION
                     SULFUR   MAGNESIUM   WATER   NITROGEN       SLURRY CONC.,GM MGO/100ML=     0.0
  NOX SCRUBBER
   INPUT,#/HR         4.90       0.0      748.3    *****
   OUTPUT,#/HR        0.08       0.0      572.8    *****

PHYSICAL PROPERTIES OF
RECYCLED SLURRY

  PH                      0.0
  CONDUCT.MICROMHOS           0.
  SPECIFIC GRAVITY         0.0



NOX   = PDS ANALYSIS
NOX*1 = SALTSMAN ANALYSIS
NOX*2 = FUEL CELL ANALYSIS

** OXIDIZED NITROGEN ONLY
```

```
                        MAGNESIUM BASE SLURRY SCRUBBING PROGRAM-OUTPUT DATA PAGE 1

  RUN NUMBER  7-C          DATE 9-23-71      TIME [illegible] DAY 1130

FLUE GAS DATA              FLOW    TEMP.      SO2      SO3      NOX     FLYASH     HUM.     DEW      DRY      STAT
                           #/HR      F        PPM      PPM      PPM     GR/DSCF    #/#     POINT    FLOW      PRES
                                                                                             F      #/HR    IN.H2O
  PRIMARY AIR              491.    110.0   ------    -----    -----    -------    0.012    67.8     485.     14.9
  SECONDARY AIR           4608.    710.0   ------    -----    -----    -------    0.012    66.5    4554.      5.3
  FURNACE EXIT            5482.    560.0   1799.0    *****    *****    *******    0.052   113.0    5210.     -0.1
  PART.SCRB.INLET         5482.    470.0   ******    *****    *****    *******    0.052   113.0    -----      2.7
  PART.CYC.EXIT           3546.    138.0   1614.5    *****    *****    *******    0.131   142.0    3136.     -6.8
  VENT ABS.INLET          *****   ******   ******    *****    *****    *******   ******   *****    -----    *****
  ABS CYC.EXIT            *****   ******   ******    *****    *****    *******   ******   *****    -----    *****
  FLOATING BED IN         3546.    138.0   ******    *****    *****    *******    0.131   142.0    -----     -6.8
  FLOATING BED EX         3715.      0.0   ******    *****    *****    *******    0.160   147.7    -----    -13.5
  P.P. EXIT ORIF.         3715.    130.0     21.2    *****     563.    *******    0.160   147.7    3202.    -13.5

SCRUBBER STREAM DATA                                                   VENTURI ABSORBER        FBA
  PARTICULATE             TEMP,F   FLOW,GPM          GAS ABSORBER     TEMP,F FLOW,#/M  TEMP,F  FLOW,#/M
   MAKEUP WATER            60.0      0.0              MAKEUP WATER    *****    *****     60.0      0.6
   PRODUCT LIQ.           138.0      0.0              MAKEUP MGO SL.  *****      3.6      0.0      3.6
   RECIRCULATED LIQ.      139.0     20.02             PRODUCT LIQ.    *****    *****    136.0      0.0
                                                      REC.(SPRAY NOZ) *****    *****    136.0      0.0
                                                      REC.(FLOW NOZ.)          *****             380.0

FURNACE PERFORMANCE                          SCRUBBER PERFORMANCE        PART.    VENT ABS.    FLOAT.BED
  HEAT RELEASE,BTU/HR    0.510E 07             SO2 ABSORB.EFF            10.26     ******        98.69
  %   FUEL AS COAL            96.1             FLYASH COL.EFF           ******     ******       ******
  COAL FLOW RATE,#/HR        402.6             SO3 ABSORB.EFF           ******     ******       ******
  NAT.GAS FLOW,#/HR            8.9             NOX ABSORB.EFF           ******     ******       ******
  %   EXCESS AIR              20.0             GAS VELOCITY,FPS           96.0     ******          6.2
  OXYGEN,%DRY,MEAS.           4.20             LIQ/GAS,GAL/MCF            21.0     ******         57.5
  CO2,%DRY-CALC.             14.42             LIQ/GAS,#/#                 2.8     ******          6.1
  HUMIDITY,#/# - CALC.       0.052             PRES.DROP,IN.WG             3.1     ******          4.4

SO2 ABSORPTION PARAMETERS                                                 SULFATE FORMATION PARAMETERS
  VENTURI ABSORBER                  FLOATING BED ABSORBER
                                                                            CONC.,GM-MOLE/L=  ******
  KGA,#MOLE/HR-FT3,     = ******     KGA,#MOLE/HR-FT3        =    28.8      MOL% TOTAL SULF=  *****
  SULFITE/SO2-MOL/MOL = ******      SULFITE/SO2-MOL/MOL     =   32.06      O2 AT FURN. EX.=   4.20
  SUMP RESID.TIME,MIN = ******      SUMP RESID.TIME,MIN     =  ******      O2 AT ABSORB.IN=  *****
                                                                             O2 AT ABSORB.EX=  *****

  ***** MEANS ITEM NOT MEASURED
```

B-20

```
                  MAGNESIUM BASE SLURRY SCRUBBING PROGRAM - OUTPUT DATA PAGE 2

   RUN NUMBER  7-C          DATE 9-23-71     TIME OF DAY 1130

MATERIAL BALANCES                                                    INPUT FOR EQ. - KIN.PROG.
                       SULFUR   MAGNESIUM  FLYASH    WATER    DRY GAS
  FURNACE                                                            INPUT FLOWS,#ATOMS/100#FEED
    INPUT,#/HR          14.90    ------     29.80    253.1     5203.   CARBON      0.450212
    OUTPUT,#/HR          9.81    ------    ******    272.3     5210.   HYDROGEN    0.560042
                                                                       OXYGEN      1.396197
  PART.SCRUBBER                                                        NITROGEN    5.071530
    INPUT,#/HR           9.81    ------    ******    335.      5210.   SULFUR      0.008542
    OUTPUT,#/HR          5.30    ------    ******    411.      3136.
                                                                      FEED RATE,#/SEC=   1.51
  SO2 ABSORBERS
    INPUT,#/HR           5.30    ******    ******    663.      3136.  ENTHALPY,BTU/# =   -1315.
    OUTPUT,#/HR          0.07    ******    ******    513.      3202.
*
*SO2 ABSORBERS-        GM SO2/   GM-MOLE/    GRAM/        MAKEUP MGO COMPOSITION
 PRODUCT COMP.         100ML     LITER       100ML         SLURRY CONC.- GM MGO/100ML =     ******
                                                           MGO PRESLAKED, NO=0, YES=1            0
  TOTAL,                1.41     0.2209     ------         % SLAKED TO MG(OH)2,MEAS.  =     ******
  COMBINED              1.41     0.2209     ------
  FREE                  0.0      0.0        ------        PRODUCT MG BASE PHYSICAL PROPERTIES
  MONO(TOTAL)           1.41     0.2209     ------         ACID STRENGTH, PH      =    3.10
  MONO(DISSOLVED)       1.52     0.2375      2.470         SP.GRAVITY,HYDROM.     =   *******
  MONO(SOLID)          -0.11     -.0166     -0.353
  BISULFITE             0.0      0.0         0.0
  MGO                   0.79     0.1230      0.492
  SULFATE              *****     ******     ******        PARTICULATE SCRUBBER PRODUCT
  MAGNESIUM             2.20     0.3439     ------         ACID STRENGTH , PH      =    5.50
  FLYASH               -----     ------     ******         FLYASH CONC. GM/100ML   =  *****
  SOLIDS,MG            -----     ------      2.093

  COAL COMPOSITION-MASS

    CARBON      0.7150
    HYDROGEN    0.0485
    OXY+NIT     0.0817
    SULFUR      0.0370
    ASH         0.0740
    WATER       0.0438

*
*SOLIDS FREE BASIS, MASS/VOLUME SOLUTION
```

```
RUN NUMBER  7-C           DATE 9-23-71     TIME OF DAY 1130

FLUE GAS DATA    FLOW     TEMP.     SO2      NOX      NOX*1    NOX*2    HUM.     DEW     STAT
                 #/HR      F        PPM      PPM      PPM      PPM      #/#     POINT    PRES
                                                                                  F      IN.WG
FURNACE EXIT    5482.    560.0   1799.0   ******   ******    733.2   0.052   113.0    -0.1
FLOAT.BED EX    3715.    130.0     21.2    563.4   ******    695.6   0.160   147.7   -13.5
NOX SCRUB IN    3772.    164.0   ******    504.1    324.2    714.4   0.160   147.7     1.4
NOX SCRUB EX    3816.    128.0      8.3    550.4    311.1    629.8   0.174   151.6     0.0

NOX SCRUB.DATA TEMP.  FLOW     SCRUB.PERFORMANCE         SPRAY SLURRY ANALYSIS
                 F    #/MIN      SO2 ABSORB.    61.02
MAKEUP WATER    60.0   0.81      NOX ABSORP.    -9.17      MGO,GM/100ML          0.587
MAKEUP MGO      60.0   1.05      NOX1 ABSORP     4.04      MGSO3(SOLID),M       0.0031
PRODUCT LIQ.   130.0   2.90      NOX2 ABSORP    11.84      MGSO3(TOTAL),M       0.0137
RECIRC. LIQ.   130.0  1250.      GAS VEL.FPS     1.8       MGSO4,MOLAR          0.0241
                                 L/G,GAL/MCF   142.2       MG(NO2)2, MOLAR      0.0096
NO2 FLOW DATA                    L/G,#/#        19.9       MG(NO3)2, MOLAR      0.0000
  NO2 FLOWRATE,#/MIN     0.0     PRES.DROP,WG    0.1       TSS,GM/100ML          3.326
  NO2/NO( PDS BASIS)   -0.11                               NITRITE/NITRATE    ******
  NO2/NO(FC & ROTO)      0.0

MATERIAL BALANCE                                   **      MAKEUP MGO COMPOSITION
                      SULFUR  MAGNESIUM  WATER   NITROGEN       SLURRY CONC.,GM MGO/100ML=   4.00
 NOX SCRUBBER
  INPUT,#/HR           0.07     1.51     629.7     0.75
  OUTPUT,#/HR          0.24     0.81     567.6     0.87

PHYSICAL PROPERTIES OF
RECYCLED SLURRY

  PH                  8.15
  CONDUCT.MICROMHOS    6870.
  SPECIFIC GRAVITY     1.012


NOX   = PDS ANALYSIS
NOX*1 = SALTSMAN ANALYSIS
NOX*2 = FUEL CELL ANALYSIS

** OXIDIZED NITROGEN ONLY
```

```
                                    MAGNESIUM BASE SLURRY SCRUBBINC PROGRAM-OUTPUT DATA PAGE 1

  RUN NUMBER  8-B            DATE 9-23-71      TIME OF DAY 1345

 FLUE GAS DATA               FLOW    TEMP.     SO2     SO3     NOX    FLYASH      HUM.     DEW      DRY      STAT
                             #/HR      F       PPM     PPM     PPM    GR/DSCF     #/#     POINT     FLOW     PRES
                                                                                            F       #/HR    IN.H2O
   PRIMARY AIR                488.   115.0  ------   -----   -----   -------    0.011    64.7      483.     14.9
   SECONDARY AIR             4602.   710.0  ------   -----   -----   -------    0.014    70.4     4541.      5.6
   FURNACE EXIT              5485.   590.0  1688.7   *****   *****   *******    0.055   114.5     5200.      0.0
   PART.SCRB.INLET           5485.   485.0  ******   *****   *****   *******    0.055   114.5     -----      2.7
   PART.CYC.EXIT             3535.   138.0  1557.1   *****   *****   *******    0.137   143.3     3109.     -8.1
   VENT ABS.INLET            *****  ******  ******   *****   *****   *******   ******   *****     -----    *****
   ABS CYC.EXIT              *****  ******  ******   *****   *****   *******   ******   *****     -----    *****
   FLOATING BED IN           3535.   138.0  ******   *****   *****   *******    0.137   143.3     -----     -8.1
   FLOATING BED EX           3703.     0.0  ******   *****   *****   *******    0.167   148.7     -----    -14.9
   P.P. EXIT ORIF.           3703.   130.0    13.2   *****    580.   *******    0.167   148.7     3174.    -14.9

 SCRUBBER STREAM DATA                                                  VENTURI ABSORBER       FBA
   PARTICULATE               TEMP,F    FLOW,GPM      GAS ABSORBER     TEMP,F FLOW,#/M   TEMP,F  FLOW,#/M
    MAKEUP WATER               60.0      0.0          MAKEUP WATER     *****    *****      60.0      1.0
    PRODUCT LIQ.              140.0      0.0          MAKEUP MGO SL.   *****      3.2       0.0      3.2
    RECIRCULATED LIQ.         140.0     19.78         PRODUCT LIQ.     *****    *****     137.0      0.0
                                                      REC.(SPRAY NOZ)  *****    *****     137.0      0.0
                                                      REC.(FLOW NOZ.)           *****              385.0

 FURNACE PERFORMANCE                          SCRUBBER PERFORMANCE         PART.    VENT ABS.    FLOAT.BED
   HEAT RELEASE,BTU/HR      0.523E 07          SO2 ABSORB.EFF               7.79     ******        99.15
   %   FUEL AS COAL              96.2          FLYASH COL.EFF             ******     ******       ******
   COAL FLOW RATE,#/HR          413.5          SO3 ABSORB.EFF             ******     ******       ******
   NAT.GAS FLOW,#/HR              8.9          NOX ABSORB.EFF             ******     ******       ******
   %   EXCESS AIR                17.6          GAS VELOCITY,FPS             96.3     ******          6.2
   OXYGEN,%DRY,MEAS.             3.70          LIQ/GAS,GAL/MCF              20.7     ******         58.1
   CO2,%DRY-CALC.               14.86          LIQ/GAS,#/#                   2.8     ******          6.2
   HUMIDITY,#/# - CALC.         0.055          PRES.DROP,IN.WG               3.3     ******          4.7

SO2 ABSORPTION PARAMETERS                                                   SULFATE FORMATION PARAMETERS
  VENTURI ABSORBER                      FLOATING BED ABSORBER

   KGA,#MOLE/HR-FT3,      = ******     KGA,#MOLE/HR-FT3           =    31.4      CONC.,GM-MOLE/L=  ******
   SULFITE/SO2-MOL/MOL    = ******     SULFITE/SO2-MOL/MOL        =   25.08      MOL% TOTAL SULF=  *****
   SUMP RESID.TIME,MIN    = ******     SUMP RESID.TIME,MIN        =  ******      O2 AT FURN. EX.=   3.70
                                                                                 O2 AT ABSORB.IN=  *****
 ***** MEANS ITEM NOT MEASURED                                                   O2 AT ABSORB.EX=  *****
```

```
                    MAGNESIUM BASE SLURRY SCRUBBING PROGRAM - OUTPUT DATA PAGE 2

  RUN NUMBER  8-B          DATE 9-23-71     TIME OF DAY 1345
                                                                      INPUT FOR EQ. - KIN.PROG.
MATERIAL BALANCES
                      SULFUR    MAGNESIUM   FLYASH     WATER     DRY GAS      INPUT FLOWS,#ATOMS/100#FEED
  FURNACE                                                                      CARBON      0.462460
    INPUT,#/HR         15.30     ------      30.60     265.5      5193.        HYDROGEN    0.558342
    OUTPUT,#/HR         9.13     ------     ******     284.7      5200.        OXYGEN      1.394766
                                                                               NITROGEN    5.060255
  PART.SCRUBBER                                                                SULFUR      0.008780
    INPUT,#/HR          9.18     ------     ******      321.      5200.
    OUTPUT,#/HR         5.06     ------     ******      426.      3109.       FEED RATE,#/SEC=   1.51

  SO2 ABSORBERS                                                               ENTHALPY,BTU/# =   -2326.
    INPUT,#/HR          5.06       4.61     ******      673.      3109.
    OUTPUT,#/HR         0.04     ******     ******      529.      3174.
*                                                          MAKEUP MGO COMPOSITION
*SO2 ABSORBERS-       GM SO2/    GM-MOLE/     GRAM/          SLURRY CONC.- GM MGO/100ML =       4.00
 PRODUCT COMP.        100ML      LITER        100ML          MGO PRESLAKED, NO=0, YES=1          0
                                                             % SLAKED TO MG(OH)2,MEAS.  =     ******
  TOTAL,               2.23      0.3480      ------
  COMBINED             2.23      0.3480      ------
  FREE                 0.0       0.0         ------      PRODUCT MG BASE PHYSICAL PROPERTIES
  MONO(TOTAL)          2.23      0.3480      ------        ACID STRENGTH, PH       =    8.05
  MONO(DISSOLVED)      1.12      0.1750       1.820        SP.GRAVITY,HYDROM.      =  *******
  MONO(SOLID)          1.11      0.1730       3.669
  BISULFITE            0.0       0.0          0.0
  MGO                  0.85      0.1329       0.532
  SULFATE             *****      ******      ******      PARTICULATE SCRUBBER PRODUCT
  MAGNESIUM            3.08      0.4809      ------        ACID STRENGTH , PH        =   6.35
  FLYASH              -----      ------      ******        FLYASH CONC. GM/100ML     =  *****
  SOLIDS,MG           -----      ------       2.640

  COAL COMPOSITION-MASS

    CARBON        0.7150
    HYDROGEN      0.0485
    OXY+NIT       0.0817
    SULFUR        0.0370
    ASH           0.0740
    WATER         0.0438

*
*SOLIDS FREE BASIS, MASS/VOLUME SOLUTION
```

```
RUN NUMBER  8-B            DATE 9-23-71      TIME OF DAY 1345

FLUE GAS DATA     FLOW    TEMP.     SO2      NOX      NOX*1    NOX*2     HUM.     DEW     STAT
                  #/HR     F        PPM      PPM      PPM      PPM       #/#     POINT    PRES
                                                                                   F      IN.WG
FURNACE EXIT      5485.   590.0   1688.7   ******   ******    759.6    0.055   114.5      0.0
FLOAT.BED EX      3703.   130.0     13.2    580.4   ******    873.6    0.167   148.7    -14.9
NOX SCRUB IN      3719.   164.0   ******    906.0    802.1   ******    0.167   148.7      1.4
NOX SCRUB EX      3759.   128.0   ******    947.5    566.9   ******    0.179   152.5      0.0

NOX SCRUB.DATA TEMP. FLOW     SCRUB.PERFORMANCE          SPRAY SLURRY ANALYSIS
                F    #/MIN      SO2 ABSORB.  ******
MAKEUP WATER   60.0   0.81      NOX ABSORP.    -4.58       MGO,GM/100ML            0.762
MAKEUP MGO     60.0   2.00      NOX1 ABSORP    29.33       MGSO3(SOLID),M         0.0062
PRODUCT LIQ.  130.0   2.90      NOX2 ABSORP    11.84       MGSO3(TOTAL),M         0.0065
RECIRC. LIQ.  130.0  1250.      GAS VEL.FPS     1.8        MGSO4,MOLAR            0.0192
                                L/G,GAL/MCF   143.8        MG(NO2)2, MOLAR        0.0098
NO2 FLOW DATA                   L/G,#/#        20.2        MG(NO3)2, MOLAR        0.0015
  NO2 FLOWRATE,#/MIN    0.03    PRES.DROP,WG    0.1        TSS,GM/100ML            3.037
  NO2/NO( PDS BASIS)    0.56                               NITRITE/NITRATE         6.533
  NO2/NO(FC & ROTO)     0.46

MATERIAL BALANCE                                    **     MAKEUP MGO COMPOSITION
                     SULFUR  MAGNESIUM  WATER   NITROGEN       SLURRY CONC.,GM MGO/100ML=    4.00
  NOX SCRUBBER
    INPUT,#/HR        0.04     2.88     694.6     1.32
    OUTPUT,#/HR       0.14     0.95     573.9     1.44

PHYSICAL PROPERTIES OF
RECYCLED SLURRY

   PH                    8.20
   CONDUCT.MICROMHOS     6000.
   SPECIFIC GRAVITY      1.005



NOX   = PDS ANALYSIS
NOX*1 = SALTSMAN ANALYSIS
NOX*2 = FUEL CELL ANALYSIS

** OXICIZED NITROGEN ONLY

IHC210I PROGRAM INTERRUPT(P) OLD PSW IS    FF15000 F A2016364
```

```
                        MAGNESIUM BASE SLURRY SCRUBBING PROGRAM-OUTPUT DATA PAGE 1

  RUN NUMBER  9-D            DATE 9-23-71     TIME OF DAY 1500

FLUE GAS DATA           FLOW    TEMP.    SO2     SO3     NOX    FLYASH     HUM.    DEW     DRY      STAT
                        #/HR      F      PPM     PPM     PPM    GR/DSCF    #/#    POINT    FLOW     PRES
                                                                                    F      #/HR    IN.H2O
  PRIMARY AIR            486.    120.0  ------   -----   -----  -------   0.012   66.0     481.     14.9
  SECONDARY AIR         4587.    717.5  ------   -----   -----  -------   0.012   67.4    4531.      5.7
  FURNACE EXIT          5464.    590.0   698.0   *****   *****  *******   0.053  113.8    5187.      0.0
  PART.SCRB.INLET       5464.    490.0  ******   *****   *****  *******   0.053  113.8    -----      2.7
  PART.CYC.EXIT         3543.    138.0   698.0   *****   *****  *******   0.137  143.5    3116.     -6.8
  VENT ABS.INLET        *****   ******  ******   *****   *****  *******  ******  *****    -----    *****
  ABS CYC.EXIT          *****   ******  ******   *****   *****  *******  ******  *****    -----    *****
  FLOATING BED IN       3543.    138.0  ******   *****   *****  *******   0.137  143.5    -----     -8.1
  FLOATING BED EX       3705.      0.0  ******   *****   *****  *******   0.166  148.7    -----    -14.9
  P.P. EXIT ORIF.       3705.    130.0     4.2   *****      0.  *******   0.166  148.7    3177.    -14.9

                                                                 VENTURI ABSORBER       FBA
SCRUBBER STREAM DATA                                  GAS ABSORBER  TEMP,F FLOW,#/M  TEMP,F  FLOW,#/M
  PARTICULATE             TEMP,F   FLOW,GPM            MAKEUP WATER      *****   *****      60.0      0.6
   MAKEUP WATER             60.0      0.0              MAKEUP MGO SL.    *****     3.2       0.0      3.2
   PRODUCT LIQ.            138.0      0.0              PRODUCT LIQ.      *****   *****     137.0      0.0
   RECIRCULATED LIQ.       138.0     20.02             REC.(SPRAY NOZ)   *****   *****     137.0      0.0
                                                       REC.(FLOW NOZ.)           *****              380.0

FURNACE PERFORMANCE                      SCRUBBER PERFORMANCE      PART.     VENT ABS.    FLOAT.BED
  HEAT RELEASE,BTU/HR   0.519E 07          SO2 ABSORB.EFF           -0.0      ******        99.40
  %   FUEL AS COAL           96.2          FLYASH COL.EFF         ******      ******       ******
  COAL FLOW RATE,#/HR       410.1          SO3 ABSORB.EFF         ******      ******       ******
  NAT.GAS FLOW,#/HR           8.9          NOX ABSORB.EFF         ******      ******       ******
  %   EXCESS AIR             18.1          GAS VELOCITY,FPS         96.1      ******          6.2
  OXYGEN,%DRY,MEAS.          3.80          LIQ/GAS,GAL/MCF          21.0      ******         57.3
  CO2,%DRY-CALC.            14.77          LIQ/GAS,#/#               2.8      ******          6.2
  HUMIDITY,#/# - CALC.      0.053          PRES.DROP,IN.WG           3.3      ******          4.7

SO2 ABSORPTION PARAMETERS                                          SULFATE FORMATION PARAMETERS
  VENTURI ABSORBER                FLOATING BED ABSORBER
                                                                      CONC.,GM-MOLE/L=   ******
  KGA,#MOLE/HR-FT3,     = ******    KGA,#MOLE/HR-FT3         =    33.7    MOL% TOTAL SULF=   *****
  SULFITE/SO2-MOL/MOL  = ******    SULFITE/SO2-MOL/MOL      =  ******    O2 AT FURN. EX.=    3.80
  SUMP RESID.TIME,MIN  = ******    SUMP RESID.TIME,MIN      =  ******    O2 AT ABSORB.IN=   *****
                                                                      O2 AT ABSORB.EX=   *****

 ***** MEANS ITEM NOT MEASURED
```

```
                 MAGNESIUM BASE SLURRY SCRUBBING PROGRAM - OUTPUT DATA PAGE 2

   RUN NUMBER  9-D          DATE 9-23-71     TIME OF DAY 1500

MATERIAL BALANCES                                                      INPUT FOR EQ. - KIN.PROG.
                     SULFUR    MAGNESIUM  FLYASH     WATER     DRY GAS
  FURNACE                                                              INPUT FLOWS,#ATOMS/100#FEED
    INPUT,#/HR        15.17     ------      30.35     257.9      5180.    CARBON       0.459998
    OUTPUT,#/HR        3.78     ------     ******     277.1      5187.    HYDROGEN     0.561502
                                                                          OXYGEN       1.395050
  PART.SCRUBBER                                                           NITROGEN     5.062521
    INPUT,#/HR         3.78     ------     ******     340.       5187.    SULFUR       0.008732
    OUTPUT,#/HR        2.27     ------     ******     426.       3116.
                                                                         FEED RATE,#/SEC=   1.51
  SO2 ABSORBERS
    INPUT,#/HR         2.27     ******     ******     654.       3116.   ENTHALPY,BTU/# =   -1499.
    OUTPUT,#/HR      ******     ******     ******     527.       3177.
*
*SO2 ABSORBERS-      GM SO2/   GM-MOLE/     GRAM/          MAKEUP MGO COMPOSITION
 PRODUCT COMP.       100ML     LITER        100ML           SLURRY CONC.- GM MGO/100ML =     ******
                                                            MGO PRESLAKED, NO=0, YES=1           0
  TOTAL,             *****     ******       ------          % SLAKED TO MG(OH)2,MEAS.  =     ******
  COMBINED           *****     ******       ------
  FREE               *****     ******       ------         PRODUCT MG BASE PHYSICAL PROPERTIES
  MONO(TOTAL)        *****     ******       ------          ACID STRENGTH, PH       =   *****
  MONO(DISSOLVED)    *****     ******       ******          SP.GRAVITY,HYDROM.      =   *******
  MONO(SOLID)        *****     ******       ******
  BISULFITE          *****     ******       ******
  MGO                *****     ******       ******
  SULFATE            *****     ******       ******         PARTICULATE SCRUBBER PRODUCT
  MAGNESIUM          *****     ******       ------          ACID STRENGTH , PH      =  *****
  FLYASH             -----     ------       ******          FLYASH CONC. GM/100ML   =  *****
  SOLIDS,MG          -----     ------       ******

  COAL COMPOSITION-MASS

    CARBON      0.7150
    HYDROGEN    0.0485
    OXY+NIT     0.0817
    SULFUR      0.0370
    ASH         0.0740
    WATER       0.0438

*
```

```
RUN NUMBER  9-D           DATE 9-23-71      TIME OF DAY 1500

FLUE GAS DAT.    FLOW     TEMP.      SO2      NOX      NOX*1     NOX*2     HUM.     DEW     STAT
                 #/HR      F         PPM      PPM      PPM       PPM       #/#     POINT    PRES
                                                                                    F      IN.WG
FURNACE EXIT    5464.    590.0     698.0   ******    ******    ******    0.053   113.8      0.0
FLOAT.BED EX    3705.    130.0       4.2      0.0    ******    ******    0.166   148.7    -14.9
NOX SCRUB IN    3715.    166.0    ******   1026.2     937.1    ******    0.166   148.7      1.4
NOX SCRUB EX    3758.    128.0    ******    717.5     857.8     773.6    0.179   152.6      0.0

NOX SCRUB.DATA TEMP.  FLOW     SCRUB.PERFORMANCE          SPRAY SLURRY ANALYSIS
                 F    #/MIN      SO2 ABSORB.   ******
                                 NOX ABSORP.    30.08       MGO,GM/100ML          0.900
MAKEUP WATER    60.0   0.81      NOX1 ABSORP     8.46       MGSO3(SOLID),M       0.0031
MAKEUP MGO      60.0   2.30      NOX2 ABSORP    11.84       MGSO3(TOTAL),M       0.0037
PRODUCT LIQ.   130.0   3.20      GAS VEL.FPS     1.8        MGSO4,MOLAR          0.0134
RECIRC. LIQ.   130.0  1250.      L/G,GAL/MCF   143.7        MG(NO2)2, MOLAR      0.0124
                                 L/G,#/#        20.2        MG(NO3)2, MOLAR      0.0003
NO2 FLOW DATA                    PRES.DROP,WG    0.1        TSS,GM/100ML          3.373
  NO2 FLOWRATE,#/MIN     0.06                               NITRITE/NITRATE     41.333
  NO2/NO( PDS BASIS)    *****
  NO2/NO(FC & ROTO)     *****

                                                    **       MAKEUP MGO COMPOSITION
MATERIAL BALANCE                                                SLURRY CONC.,GM MGO/100ML=    4.00
                         SULFUR   MAGNESIUM   WATER   NITROGEN

  NOX SCRUBBER
    INPUT,#/HR            0.01       3.31     709.9      1.50
    OUTPUT,#/HR           0.11       1.17     575.0      1.11

  PHYSICAL PROPERTIES OF
  RECYCLED SLURRY

     PH                       8.20
     CONDUCT.MICROMHOS       6080.
     SPECIFIC GRAVITY        1.010



  NOX    = PDS ANALYSIS
  NOX*1  = SALTSMAN ANALYSIS
  NOX*2  = FUEL CELL ANALYSIS

  ** OXIDIZED NITROGEN ONLY
```

B-28

```
                       MAGNESIUM BASE SLURRY SCRUBBING PROGRAM-OUTPUT DATA PAGE 1

  RUN NUMBER  10-G          DATE 9-24-71      TIME OF DAY 1200

FLUE GAS DATA            FLOW    TEMP.    SO2     SO3     NOX    FLYASH    HUM.    DEW      DRY      STAT
                         #/HR     F       PPM     PPM     PPM    GR/DSCF   #/#     POINT    FLOW     PRES
                                                                                     F      #/HR    IN.H2O
  PRIMARY AIR            482.   110.0   ------  -----   -----  -------   0.008    56.9     478.     14.9
  SECONDARY AIR         4640.   690.0   ------  -----   -----  -------   0.012    66.9    4585.      5.2
  FURNACE EXIT          5516.   490.0   1733.4  *****   *****  *******   0.053   113.7    5239.      0.0
  PART.SCRB.INLET       5516.   410.0   ******  *****   *****  *******   0.053   113.7    -----      2.7
  PART.CYC.EXIT         3639.   130.0   1595.7  *****   *****  *******   0.119   139.2    3251.     -8.1
  VENT ABS.INLET        *****  ******   ******  *****   *****  *******  ******   *****    -----    *****
  ABS CYC.EXIT          *****  ******   ******  *****   *****  *******  ******   *****    -----    *****
  FLOATING BED IN       3639.   130.0   ******  *****   *****  *******   0.119   139.2    -----     -8.1
  FLOATING BED EX       3798.     0.0   ******  *****   *****  *******   0.147   145.0    -----    -14.9
  P.P. EXIT ORIF.       3798.   125.0      4.1  *****    609.  *******   0.147   145.0    3312.    -14.9

SCRUBBER STREAM DATA                                                VENTURI ABSORBER        FBA
  PARTICULATE            TEMP,F    FLOW,GPM        GAS ABSORBER     TEMP,F FLOW,#/M   TEMP,F  FLOW,#/M
   MAKEUP WATER           60.0       0.0            MAKEUP WATER     *****   *****      60.0      0.6
   PRODUCT LIQ.          132.0       0.0            MAKEUP MGO SL.   *****     3.5       0.0      3.5
   RECIRCULATED LIQ.     132.0      19.78           PRODUCT LIQ.     *****   *****     130.0      0.0
                                                    REC.(SPRAY NOZ)  *****   *****     130.0      0.0
                                                    REC.(FLOW NOZ.)          *****              385.0

FURNACE PERFORMANCE                        SCRUBBER PERFORMANCE       PART.     VENT ABS.     FLOAT.BED
  HEAT RELEASE,BTU/HR    0.524E 07           SO2 ABSORB.EFF          10.53      ******         99.74
  %   FUEL AS COAL            96.2           FLYASH COL.EFF         ******      ******        ******
  COAL FLOW RATE,#/HR        414.1           SO3 ABSORB.EFF         ******      ******        ******
  NAT.GAS FLOW,#/HR            9.1           NOX ABSORB.EFF         ******      ******        ******
  %   EXCESS AIR              18.1           GAS VELOCITY,FPS         96.3      ******           6.3
  OXYGEN,%DRY,MEAS.           3.80           LIQ/GAS,GAL/MCF          20.7      ******          57.5
  CO2,%DRY-CALC.             14.77           LIQ/GAS,#/#               2.7      ******           6.1
  HUMIDITY,#/# - CALC.       0.053           PRES.DROP,IN.WG           3.5      ******           5.2

SO2 ABSORPTION PARAMETERS                                                SULFATE FORMATION PARAMETERS
  VENTURI ABSORBER                 FLOATING BED ABSORBER
                                                                          CONC.,GM-MOLE/L=  ******
  KGA,#MOLE/HR-FT3,     = ******    KGA,#MOLE/HR-FT3       =    40.9      MOL% TOTAL SULF=  *****
  SULFITE/SO2-MOL/MOL   = ******    SULFITE/SO2-MOL/MOL    =    28.05     O2 AT FURN. EX.=   3.80
  SUMP RESID.TIME,MIN   = ******    SUMP RESID.TIME,MIN    =  ******      O2 AT ABSORB.IN=  *****
                                                                          O2 AT ABSORB.EX=  *****

  ***** MEANS ITEM NOT MEASURED
```

```
                MAGNESIUM BASE SLURRY SCRUBBING PROGRAM - OUTPUT DATA PAGE 2

   RUN NUMBER  10-G          DATE 9-24-71      TIME OF DAY 1200

MATERIAL BALANCES                                                        INPUT FOR EQ. - KIN.PROG.
                   SULFUR   MAGNESIUM  FLYASH    WATER    DRY GAS
  FURNACE                                                                INPUT FLOWS,#ATOMS/100#FEED
    INPUT,#/HR      15.32    ------     30.64    257.6     5232.           CARBON      0.459919
    OUTPUT,#/HR      9.77    ------    ******    277.2     5239.           HYDROGEN    0.528744
                                                                           OXYGEN      1.395043
  PART.SCRUBBER                                                            NITROGEN    5.062600
    INPUT,#/HR       9.77    ------    ******    340.      5239.           SULFUR      0.008727
    OUTPUT,#/HR      5.42    ------    ******    388.      3251.
                                                                          FEED RATE,#/SEC=   1.52
  SO2 ABSORBERS
    INPUT,#/HR       5.42     7.41     ******    625.      3251.          ENTHALPY,BTU/# =   -1857.
    OUTPUT,#/HR      0.01    ******    ******    486.      3312.
*
*SO2 ABSORBERS-    GM SO2/   GM-MOLE/    GRAM/       MAKEUP MGO COMPOSITION
 PRODUCT COMP.     100ML     LITER       100ML        SLURRY CONC.- GM MGO/100ML =       5.80
                                                      MGO PRESLAKED, NO=0, YES=1             0
  TOTAL,            3.05     0.4764     ------        % SLAKED TO MG(OH)2,MEAS.  =     ******
  COMBINED          3.05     0.4764     ------
  FREE              0.0      0.0        ------       PRODUCT MG BASE PHYSICAL PROPERTIES
  MONO(TOTAL)       3.05     0.4764     ------        ACID STRENGTH, PH      =     7.95
  MONO(DISSOLVED)   1.34     0.2094      2.177        SP.GRAVITY,HYDROM.     =     1.0200
  MONO(SOLID)       1.71     0.2670      5.660
  BISULFITE         0.0      0.0         0.0
  MGO               0.59     0.0921      0.368
  SULFATE          *****    ******      ******       PARTICULATE SCRUBBER PRODUCT
  MAGNESIUM         3.64     0.5684     ------        ACID STRENGTH , PH      =  *****
  FLYASH           -----    ------      ******        FLYASH CONC. GM/100ML   =  *****
  SOLIDS,MG        -----    ------       3.161

 COAL COMPOSITION-MASS

   CARBON       0.7150
   HYDROGEN     0.0485
   OXY+NIT      0.0817
   SULFUR       0.0370
   ASH          0.0740
   WATER        0.0438

*SOLIDS FREE BASIS, MASS/VOLUME SOLUTION
```

```
RUN NUMBER  10-G          DATE 9-24-71     TIME OF DAY 1200

FLUE GAS DATA    FLOW    TEMP.    SO2     NOX      NOX*1    NOX*2    HUM.    DEW     STAT
                 #/HR     F       PPM     PPM      PPM      PPM      #/#     POINT   PRES
                                                                              F      IN.WG
FURNACE EXIT     5516.   490.0  1783.4  ******   ******    692.4    0.053   113.7     0.0
FLOAT.BED EX     3798.   125.0     4.1   608.8   ******    645.6    0.147   145.0   -14.9
NOX SCRUB IN     3761.   160.0  ******   766.0    680.8    729.9    0.147   145.0     1.4
NOX SCRUB FX     3807.   122.0  ******  1709.5    491.6    655.0    0.161   149.4     0.0

NOX SCRUB.DATA TEMP. FLOW     SCRUB.PERFORMANCE        SPRAY SLURRY ANALYSIS
                 F    #/MIN     SO2 ABSORB.   ******
MAKEUP WATER   60.0   0.81      NOX ABSORP.   ******     MGO,GM/100ML          0.562
MAKEUP MGO     60.0   2.90      NOX1 ABSORP    27.79     MGSO3(SOLID),M       0.0031
PRODUCT LIQ.  123.0   4.00      NCX2 ABSORP    10.26     MGSO3(TOTAL),M       0.0035
RECIRC. LIQ.  123.0  1250.      GAS VEL.FPS     1.8      MGSO4,MOLAR          0.0070
                                L/G,GAL/MCF   145.4      MG(NO2)2, MOLAR      0.0055
NO2 FLOW DATA                   L/G,#/#        19.9      MG(NO3)2, MOLAR      0.0006
  NO2 FLOWRATE,#/MIN    0.03    PRES.DROP,WG    0.1      TSS,GM/100ML          1.576
  NO2/NO( PDS BASIS)    0.26                             NITRITE/NITRATE      9.167
  NO2/NO(FC & ROTO)     0.65

MATERIAL BALANCE                                  **      MAKEUP MGO COMPOSITION
                   SULFUR  MAGNESIUM  WATER    NITROGEN       SLURRY CONC.,GM MGO/100ML=    5.00
 NOX SCRUBBER
  INPUT,#/HR        0.01     5.22     695.0      1.15
  OUTPUT,#/HR       0.08     0.91     530.8      2.60

PHYSICAL PROPERTIES OF
RECYCLED SLURRY

  PH                     8.25
  CONDUCT.MICROMHOS       660.
  SPECIFIC GRAVITY       1.020



NOX   = PDS ANALYSIS
NOX*I = SALTSMAN ANALYSIS
NOX*2 = FUEL CELL ANALYSIS

** OXIDIZED NITROGEN ONLY
```

```
                        MAGNESIUM BASE SLURRY SCRUBBING PROGRAM-OUTPUT DATA PAGE 1

  RUN NUMBER  11-H          DATE 9-24-71      TIME OF DAY 1330

FLUE GAS DATA                FLOW    TEMP.     SO2     SO3     NOX    FLYASH    HUM.    DEW      DRY      STAT
                             #/HR      F       PPM     PPM     PPM   GR/DSCF    #/#    POINT    FLOW     PRES
                                                                                          F      #/HR    IN.H2O
  PRIMARY AIR                480.    110.0   ------   -----   -----  -------   0.009   58.4      476.     13.5
  SECONDARY AIR             4702.    691.3   ------   -----   -----  -------   0.014   72.0     4636.      5.7
  FURNACE EXIT              5581.    540.0   1801.2   *****   *****  *******   0.055  114.8     5290.     -0.1
  PART.SCRB.INLET           5581.    450.0   ******   *****   *****  *******   0.055  114.8     -----      4.1
  PART.CYC.EXIT             3548.    139.0   1465.8   *****   *****  *******   0.129  141.6     3143.     -8.1
  VENT ABS.INLET            *****   ******   ******   *****   *****  *******  ******  *****     -----    *****
  ABS CYC.EXIT              *****   ******   ******   *****   *****  *******  ******  *****     -----    *****
  FLOATING BED IN           3548.    135.0   ******   *****   *****  *******   0.129  141.6     -----     -8.1
  FLOATING BED EX           3721.      0.0   ******   *****   *****  *******   0.157  147.2     -----    -14.9
  P.P. EXIT ORIF.           3721.    130.0     30.9   *****    470.  *******   0.157  147.2     3214.    -14.9

SCRUBBER STREAM DATA                                          VENTURI ABSORBER       FBA
  PARTICULATE               TEMP,F   FLOW,GPM      GAS ABSORBER      TEMP,F FLOW,#/M  TEMP,F  FLOW,#/M
   MAKEUP WATER              60.0      0.0          MAKEUP WATER       *****    *****     60.0     0.6
   PRODUCT LIQ.             137.0      0.0          MAKEUP MGO SL.     *****      3.2      0.0     3.2
   RECIRCULATED LIQ.        137.0     19.78         PRODUCT LIQ.       *****    *****    136.0     0.0
                                                    REC.(SPRAY NOZ)    *****    *****    136.0     0.0
                                                    REC.(FLOW NOZ.)             *****            385.0

FURNACE PERFORMANCE                      SCRUBBER PERFORMANCE        PART.     VENT ABS.    FLOAT.BED
  HEAT RELEASE,BTU/HR    0.529E 07         SO2 ABSORB.EFF            18.62      ******        97.89
  %   FUEL AS COAL            96.2         FLYASH COL.EFF           ******      ******       ******
  COAL FLOW RATE,#/HR        418.3         SO3 ABSORB.EFF           ******      ******       ******
  NAT.GAS FLOW,#/HR            9.1         NOX ABSORB.EFF           ******      ******       ******
  %   EXCESS AIR              18.1         GAS VELOCITY,FPS           96.0      ******          6.2
  OXYGEN,%DRY,MEAS.           3.80         LIQ/GAS,GAL/MCF            20.8      ******         58.3
  CO2,%DRY-CALC.             14.77         LIQ/GAS,#/#                 2.8      ******          6.2
  HUMIDITY,#/# - CALC.       0.055         PRES.DROP,IN.WG             5.7      ******          5.6

SO2 ABSORPTION PARAMETERS                                             SULFATE FORMATION PARAMETERS
  VENTURI ABSORBER                   FLOATING BED ABSORBER
                                                                       CONC.,GM-MOLE/L=   ******
  KGA,#MOLE/HR-FT3,     = ******     KGA,#MOLE/HR-FT3        =    25.7   MOL% TOTAL SULF=   *****
  SULFITE/SO2-MOL/MOL   = ******     SULFITE/SO2-MOL/MOL     =   32.40   O2 AT FURN. EX.=    3.80
  SUMP RESID.TIME,MIN   = ******     SUMP RESID.TIME,MIN     =  ******   O2 AT ABSORB.IN=   *****
                                                                       O2 AT ABSORB.EX=   *****
  ***** MEANS ITEM NOT MEASURED
```

```
                    MAGNESIUM BASE SLURRY SCRUBBING PROGRAM - OUTPUT DATA PAGE 2

   RUN NUMBER  11-H          DATE 9-24-71     TIME OF DAY 1330

MATERIAL BALANCES                                                    INPUT FOR EQ. - KIN.PROG.
                    SULFUR    MAGNESIUM  FLYASH     WATER     DRY GAS
  FURNACE                                                            INPUT FLOWS,#ATOMS/100#FEED
    INPUT,#/HR       15.48     ------     30.95     271.0      5283.   CARBON      0.459979
    OUTPUT,#/HR       9.96     ------    ******     290.5      5290.   HYDROGEN    0.533617
                                                                       OXYGEN      1.395048
  PART.SCRUBBER                                                        NITROGEN    5.062540
    INPUT,#/HR        9.96     ------    ******      354.      5290.   SULFUR      0.008731
    OUTPUT,#/HR       4.82     ------    ******      406.      3143.
                                                                      FEED RATE,#/SEC=   1.54
  SO2 ABSORBERS
    INPUT,#/HR        4.82       6.68    ******      622.      3143.  ENTHALPY,BTU/# =   -2870.
    OUTPUT,#/HR       0.10    ******     ******      506.      3214.
*
*SO2 ABSORBERS-     GM SO2/   GM-MOLE/    GRAM/       MAKEUP MGO COMPOSITION
 PRODUCT COMP.      100ML     LITER       100ML         SLURRY CONC.- GM MGO/100ML =       5.80
                                                        MGO PRESLAKED, NO=0, YES=1            C
  TOTAL,             4.06     0.6344     ------         % SLAKED TO MG(OH)2,MEAS.  =     ******
  COMBINED           4.06     0.6344     ------
  FREE               0.0      0.0        ------       PRODUCT MG BASE PHYSICAL PROPERTIES
  MONO(TOTAL)        4.06     0.6344     ------         ACID STRENGTH, PH      =    8.00
  MONO(DISSOLVED)    1.38     0.2156      2.242         SP.GRAVITY,HYDROM.     =  *******
  MONO(SOLID)        2.68     0.4188      8.878
  BISULFITE          0.0      0.0         0.0
  MGO                1.25     0.1960      0.784
  SULFATE           *****    ******     ******        PARTICULATE SCRUBBER PRODUCT
  MAGNESIUM          5.31     0.8303     ------         ACID STRENGTH , PH      =   6.70
  FLYASH            -----    ------     ******          FLYASH CONC. GM/100ML  =  *****
  SOLIDS,MG         -----    ------     11.655

  COAL COMPOSITION-MASS

    CARBON      0.7150
    HYDROGEN    0.0485
    OXY+NIT     0.0817
    SULFUR      0.0370
    ASH         0.0740
    WATER       0.0438

*
*SOLIDS FREE BASIS, MASS/VCLUME SOLUTION
```

```
RUN NUMBER  11-H          DATE 9-24-71      TIME OF DAY 1330

FLUE GAS DATA     FLOW    TEMP.     SO2     NOX      NOX*1     NOX*2    HUM.     DEW     STAT
                  #/HR     F        PPM     PPM      PPM       PPM      #/#     POINT    PRES
                                                                                  F      IN.WG
FURNACE EXIT     5581.    540.0  1801.2   ******   ******     748.7   0.055   114.8     -0.1
FLOAT.BED EX     3721.    130.0    30.9    469.5   ******     664.4   0.157   147.2    -14.9
NOX SCRUB IN     3688.    164.0  ******    913.9    696.2     786.1   0.157   147.2      1.4
NOX SCRUB EX     3736.    126.0  ******    274.1    509.7     505.3   0.172   151.5      0.0

NOX SCRUB.DATA TEMP. FLOW     SCRUB.PERFORMANCE       SPRAY SLURRY ANALYSIS
                F    #/MIN      SO2 ABSORB.   ******
MAKEUP WATER   60.0   0.81      NOX ABSORP.    70.00     MGO,GM/100ML           0.450
MAKEUP MGO     60.0   4.15      NOX1 ABSORP    26.79     MGSO3(SOLID),M        0.0031
PRODUCT LIQ.  128.0   4.80      NOX2 ABSORP    35.71     MGSO3(TOTAL),M        0.0033
RECIRC. LIQ.  128.0  1250.      GAS VEL.FPS      1.8     MGSO4,MOLAR           0.0056
                                L/G,GAL/MCF  146.4       MG(NO2)2, MOLAR       0.0119
NO2 FLOW DATA                   L/G,#/#        20.3      MG(NO3)2, MOLAR       0.0027
  NO2 FLOWRATE,#/MIN    0.03    PRES.DROP,WG    0.1      TSS,GM/100ML           1.409
  NO2/NO( PDS BASIS)    0.95                             NITRITE/NITRATE        4.407
  NO2/NO(FC & ROTO)     0.65

MATERIAL BALANCE                                     **      MAKEUP MGO COMPOSITION
                        SULFUR  MAGNESIUM  WATER   NITROGEN       SLURRY CONC.,GM MGO/100ML=    5.00
  NOX SCRUBBER
   INPUT,#/HR            0.10     7.47     787.0     1.33
   OUTPUT,#/HR           0.08     0.94     554.0     0.52

PHYSICAL PROPERTIES OF
RECYCLED SLURRY

   PH                      8.05
   CONDUCT.MICROMHOS        535.
   SPECIFIC GRAVITY        1.050



NOX    = PDS ANALYSIS
NOX*1  = SALTSMAN ANALYSIS
NOX*2  = FUEL CELL ANALYSIS

** OXIDIZED NITROGEN ONLY
```

```
                       MAGNESIUM BASE SLURRY SCRUBBING PROGRAM-OUTPUT DATA PAGE 1

  RUN NUMBER  12-A         DATE 9-24-71     TIME OF DAY 1430

 FLUE GAS DATA            FLOW   TEMP.     SO2     SO3     NOX    FLYASH     HUM.    DEW      DRY      STAT
                          #/HR     F       PPM     PPM     PPM    GR/DSCF    #/#    POINT    FLOW     PRES
                                                                                      F      #/HR    IN.H2O
   PRIMARY AIR             481.   110.0  ------   -----   -----   -------   0.010   62.7     476.     14.9
   SECONDARY AIR          4704.   692.5  ------   -----   -----   -------   0.014   72.0    4638.      5.8
   FURNACE EXIT           5583.   560.0  1741.8   *****   *****   *******   0.055  114.9    5292.      0.0
   PART.SCRB.INLET        5583.   460.0  ******   *****   *****   *******   0.055  114.9    -----      2.7
   PART.CYC.EXIT          3550.   138.0  1479.5   *****   *****   *******   0.132  142.3    3137.     -8.1
   VENT ABS.INLET         *****  ******  ******   *****   *****   *******  ******  *****    -----    *****
   ABS CYC.EXIT           *****  ******  ******   *****   *****   *******  ******  *****    -----    *****
   FLOATING BED IN        3550.   135.0  ******   *****   *****   *******   0.132  142.3    -----     -8.1
   FLOATING BED EX        3713.     0.0  ******   *****   *****   *******   0.160  147.7    -----    -14.9
   P.P. EXIT ORIF.        3713.   132.0    30.9   *****    502.   *******   0.160  147.7    3201.    -14.9

 SCRUBBER STREAM DATA                                                 VENTURI ABSORBER       FBA
   PARTICULATE            TEMP,F   FLOW,GPM        GAS ABSORBER       TEMP,F FLOW,#/M   TEMP,F  FLOW,#/M
    MAKEUP WATER           60.0      0.0            MAKEUP WATER      *****    *****      60.0      0.6
    PRODUCT LIQ.          138.0      0.0            MAKEUP MGO SL.    *****      3.2       0.0      3.2
    RECIRCULATED LIQ.     138.0     19.78           PRODUCT LIQ.      *****    *****     136.0      0.0
                                                    REC.(SPRAY NOZ)   *****    *****     136.0      0.0
                                                    REC.(FLOW NOZ.)            *****              385.0

 FURNACE PERFORMANCE                         SCRUBBER PERFORMANCE         PART.     VENT ABS.     FLOAT.BED
   HEAT RELEASE,BTU/HR     0.529E 07          SO2 ABSORB.EFF              15.06      ******         97.91
   %    FUEL AS COAL            96.2          FLYASH COL.EFF             ******      ******        ******
   COAL FLOW RATE,#/HR         418.4          SO3 ABSORB.EFF             ******      ******        ******
   NAT.GAS FLOW,#/HR             9.1          NOX ABSORB.EFF             ******      ******        ******
   %    EXCESS AIR              18.1          GAS VELOCITY,FPS             95.9      ******           6.2
   OXYGEN,%DRY,MEAS.            3.80          LIQ/GAS,GAL/MCF              20.8      ******          58.4
   CO2,%DRY-CALC.              14.77          LIQ/GAS,#/#                   2.8      ******           6.2
   HUMIDITY,#/# - CALC.        0.055          PRES.DROP,IN.WG               3.3      ******           6.0

SO2 ABSORPTION PARAMETERS                                               SULFATE FORMATION PARAMETERS
   VENTURI ABSORBER                FLOATING BED ABSORBER
                                                                          CONC.,GM-MOLE/L=  ******
   KGA,#MOLE/HR-FT3,      = ******    KGA,#MOLE/HR-FT3          =    25.7    MOL% TOTAL SULF=  *****
   SULFITE/SO2-MOL/MOL = ******    SULFITE/SO2-MOL/MOL       =   31.77    O2 AT FURN. EX.=   3.80
   SUMP RESID.TIME,MIN = ******    SUMP RESID.TIME,MIN       =  ******    O2 AT ABSORB.IN=  *****
                                                                          O2 AT ABSORB.EX=  *****
  ***** MEANS ITEM NOT MEASURED
```

B-35

```
                    MAGNESIUM BASE SLURRY SCRUBBING PROGRAM - OUTPUT DATA PAGE 2

   RUN NUMBER  12-A        DATE 9-24-71     TIME OF DAY 1430

MATERIAL BALANCES                                                      INPUT FOR EQ. - KIN.PROG.
                 SULFUR   MAGNESIUM  FLYASH    WATER     DRY GAS
  FURNACE                                                              INPUT FLOWS,#ATOMS/100#FEED
    INPUT,#/HR    15.48    ------     30.96    271.7      5285.          CARBON      0.459981
    OUTPUT,#/HR    9.63    ------    ******    291.3      5292.          HYDROGEN    0.548169
                                                                         OXYGEN      1.395048
  PART.SCRUBBER                                                          NITROGEN    5.062539
    INPUT,#/HR     9.63    ------    ******     354.      5292.          SULFUR      0.008731
    OUTPUT,#/HR    4.85    ------    ******     413.      3137.
                                                                        FEED RATE,#/SEC=   1.54
  SO2 ABSORBERS
    INPUT,#/HR     4.85     6.68     ******     630.      3137.         ENTHALPY,BTU/# =   -2906.
    OUTPUT,#/HR    0.10    ******    ******     512.      3201.
*
*SO2 ABSORBERS-  GM SO2/   GM-MOLE/    GRAM/         MAKEUP MGO COMPOSITION
 PRODUCT COMP.   100ML     LITER       100ML          SLURRY CONC.- GM MGO/100ML =      5.80
                                                      MGO PRESLAKED, NO=0, YES=1           0
  TOTAL,          4.54     0.7089      ------         % SLAKED TO MG(OH)2,MEAS.  =    ******
  COMBINED        4.54     0.7089      ------
  FREE            0.0      0.0         ------        PRODUCT MG BASE PHYSICAL PROPERTIES
  MONO(TOTAL)     4.54     0.7089      ------         ACID STRENGTH, PH      =    7.95
  MONO(DISSOLVED) 1.36     0.2125       2.210         SP.GRAVITY,HYDROM.     =   *******
  MONO(SOLID)     3.18     0.4964      10.523
  BISULFITE       0.0      0.0          0.0
  MGO             1.52     0.2375       0.950
  SULFATE        *****     ******      ******        PARTICULATE SCRUBBER PRODUCT
  MAGNESIUM       6.06     0.9464      ------         ACID STRENGTH , PH      =   6.50
  FLYASH         -----     ------      ******         FLYASH CONC. GM/100ML   =  *****
  SOLIDS,MG      -----     ------      27.151

  COAL COMPOSITION-MASS

    CARBON      0.7150
    HYDROGEN    0.0485
    OXY+NIT     0.0817
    SULFUR      0.0370
    ASH         0.0740
    WATER       0.0438

*
*SOLIDS FREE BASIS, MASS/VOLUME SOLUTION
```

```
RUN NUMBER  12-A          DATE 9-24-71      TIME OF DAY 1430

FLUE GAS DATA     FLOW     TEMP.     SO2      NOX      NOX*1     NOX*2    HUM.     DEW     STAT
                  #/HR      F        PPM      PPM      PPM       PPM      #/#     POINT    PRES
                                                                                    F      IN.WG
FURNACE EXIT     5583.    560.0   1741.8   ******   ******     748.6   0.055   114.9     0.0
FLOAT.BED EX     3713.    132.0     30.9    501.6   ******     655.0   0.160   147.7   -14.9
NUX SCRUB IN     3684.    165.0   ******   ******    442.0     842.2   0.160   147.7     1.4
NOX SCRUB EX     3730.    126.0   ******    762.0   ******     617.6   0.174   151.9     0.0

NOX SCRUB.DATA TEMP. FLOW     SCRUB.PERFORMANCE        SPRAY SLURRY ANALYSIS
                 F    #/MIN     SO2 ABSORB.  ******
MAKEUP WATER    60.0   0.81     NOX ABSORP.   70.00      MGO,GM/100ML          0.512
MAKEUP MGO      60.0   2.00     NOX1 ABSORP  ******      MGSO3(SOLID),M       0.0031
PRODUCT LIQ.   130.0   3.35     NOX2 ABSORP   26.67      MGSO3(TOTAL),M       0.0033
RECIRC. LIQ.   130.0  1250.     GAS VEL.FPS    1.8       MGSO4,MOLAR          0.0049
                                L/G,GAL/MCF  146.2       MG(NO2)2, MOLAR      0.0121
NO2 FLOW DATA                   L/G,#/#       20.4       MG(NO3)2, MOLAR      0.0028
   NO2 FLOWRATE,#/MIN   0.03    PRES.DROP,WG   0.1       TSS,GM/100ML          1.500
   NO2/NO( PDS BASIS)  *****                             NITRITE/NITRATE      4.321
   NO2/NO(FC & ROTO)    0.67

MATERIAL BALANCE                                  **      MAKEUP MGO COMPOSITION
                    SULFUR  MAGNESIUM  WATER   NITROGEN       SLURRY CONC.,GM MGO/100ML=    5.00
  NOX SCRUBBER
   INPUT,#/HR        0.10     3.60     671.0    *****
   OUTPUT,#/HR       0.05     0.73     557.2     1.19

PHYSICAL PROPERTIES OF
RECYCLED SLURRY

   PH                     7.95
   CONDUCT.MICROMHOS       824.
   SPECIFIC GRAVITY      1.010



NOX   = PDS ANALYSIS
NOX*1 = SALTSMAN ANALYSIS
NOX*2 = FUEL CELL ANALYSIS

** OXIDIZED NITROGEN ONLY
```

```
                        MAGNESIUM BASE SLURRY SCRUBBING PROGRAM-OUTPUT DATA PAGE 1

 RUN NUMBER  13-A          DATE 9-27-71     TIME OF DAY 1600

FLUE GAS DATA            FLOW    TEMP.     SO2     SO3     NOX    FLYASH    HUM.    DEW      DRY     STAT
                         #/HR      F       PPM     PPM     PPM    GR/DSCF   #/#    POINT     FLOW    PRES
                                                                                     F       #/HR   IN.H2O
  PRIMARY AIR             468.   110.0  ------   -----   -----   -------   0.017   76.9     460.     14.9
  SECONDARY AIR          4822.   690.0  ------   -----   -----   -------   0.017   76.2    4744.      5.7
  FURNACE EXIT           5696.   570.0  1713.5   *****   *****   *******   0.058  116.1    5386.     -0.1
  PART.SCRB.INLET        5696.   460.0  ******   *****   *****   *******   0.058  116.1    -----      2.7
  PART.CYC.EXIT          3381.   138.0  1116.7   *****   *****   *******   0.135  142.8    2980.     -6.8
  VENT ABS.INLET         *****  ******  ******   *****   *****   *******  ******  *****    -----    *****
  ABS CYC.EXIT           *****  ******  ******   *****   *****   *******  ******  *****    -----    *****
  FLOATING BED IN        3381.   139.0  ******   *****   *****   *******   0.135  142.8    -----    -10.8
  FLOATING BED EX        3547.     0.0  ******   *****   *****   *******   0.164  148.2    -----    -14.9
  P.P. EXIT ORIF.        3547.   132.0     8.5   *****    581.   *******   0.164  148.2    3047.    -14.9

SCRUBBER STREAM DATA                                              VENTURI ABSORBER       FBA
  PARTICULATE            TEMP,F   FLOW,GPM       GAS ABSORBER     TEMP,F FLOW,#/M  TEMP,F  FLOW,#/M
   MAKEUP WATER           60.0      0.0           MAKEUP WATER    *****   *****      60.0      0.6
   PRODUCT LIQ.          137.0      0.0           MAKEUP MGO SL.  *****     3.3       0.0      3.3
   RECIRCULATED LIQ.     137.0     19.78          PRODUCT LIQ.    *****   *****     137.0      0.0
                                                  REC.(SPRAY NOZ) *****   *****     137.0      0.0
                                                  REC.(FLOW NOZ.)         *****              385.0

FURNACE PERFORMANCE                    SCRUBBER PERFORMANCE      PART.     VENT ABS.    FLOAT.BED
  HEAT RELEASE,BTU/HR    0.539E 07       SO2 ABSORB.EFF          34.83      ******        99.24
  %   FUEL AS COAL            96.4       FLYASH COL.EFF         ******      ******       ******
  COAL FLOW RATE,#/HR        426.4       SO3 ABSORB.EFF         ******      ******       ******
  NAT.GAS FLOW,#/HR            8.9       NOX ABSORB.EFF         ******      ******       ******
  %   EXCESS AIR              18.1       GAS VELOCITY,FPS         91.9      ******          6.0
  OXYGEN,%DRY,MEAS.           3.80       LIQ/GAS,GAL/MCF          21.7      ******         60.6
  CO2,%DRY-CALC.             14.78       LIQ/GAS,#/#               2.9      ******          6.5
  HUMIDITY,#/# - CALC.       0.058       PRES.DROP,IN.WG           2.8      ******          4.1

O2 ABSORPTION PARAMETERS                                                SULFATE FORMATION PARAMETERS
 VENTURI ABSORBER                   FLOATING BED ABSORBER
                                                                     CONC.,GM-MOLE/L=  ******
  KGA,#MOLE/HR-FT3,      = ******   KGA,#MOLE/HR-FT3       =   30.8  MOL% TOTAL SULF=  *****
  SULFITE/SO2-MOL/MOL = ******      SULFITE/SO2-MOL/MOL    =  40.32  O2 AT FURN. EX.=   3.80
  SUMP RESID.TIME,MIN = ******      SUMP RESID.TIME,MIN    = ******  O2 AT ABSORB.IN=  *****
                                                                     O2 AT ABSORB.EX=  *****

 ***** MEANS ITEM NOT MEASURED
```

```
                       MAGNESIUM BASE SLURRY SCRUBBING PROGRAM - OUTPUT DATA PAGE 2

   RUN NUMBER  13-A          DATE 9-27-71     TIME OF DAY 1600

MATERIAL BALANCES                                                   INPUT FOR EQ. - KIN.PROG.
                      SULFUR    MAGNESIUM  FLYASH    WATER     DRY GAS
  FURNACE                                                           INPUT FLOWS,#ATOMS/100#FEED
    INPUT,#/HR         15.78     ------      31.55     291.0     5378.     CARBON      0.460222
    OUTPUT,#/HR         9.65     ------     ******     310.1     5386.     HYDROGEN    0.613882
                                                                            OXYGEN      1.395070
  PART.SCRUBBER                                                            NITROGEN    5.062304
    INPUT,#/HR          9.65     ------     ******      373.     5386.     SULFUR      0.008743
    OUTPUT,#/HR         3.48     ------     ******      401.     2980.
                                                                          FEED RATE,#/SEC=   1.57
  SO2 ABSORBERS
    INPUT,#/HR          3.48       5.67     ******      628.     2980.    ENTHALPY,BTU/# =    -4283.
    OUTPUT,#/HR         0.03     ******     ******      500.     3047.
*
*SO2 ABSORBERS-       GM SO2/   GM-MOLE/     GRAM/          MAKEUP MGO COMPOSITION
 PRODUCT COMP.        100ML     LITER        100ML            SLURRY CONC.- GM MGO/100ML =        4.70
                                                              MGO PRESLAKED, NO=0, YES=1            0
  TOTAL,               1.97     0.3080      ------            % SLAKED TO MG(OH)2,MEAS.  =     ******
  COMBINED             1.97     0.3080      ------
  FREE                 0.0      0.0         ------          PRODUCT MG BASE PHYSICAL PROPERTIES
  MONO(TOTAL)          1.97     0.3080      ------            ACID STRENGTH, PH      =    8.10
  MONO(DISSOLVED)      1.24     0.1937       2.015            SP.GRAVITY,HYDROM.     =   *******
  MONO(SOLID)          0.73     0.1143       2.423
  BISULFITE            0.0      0.0          0.0
  MGO                  1.77     0.2760       1.104
  SULFATE             *****     ******      ******          PARTICULATE SCRUBBER PRODUCT
  MAGNESIUM            3.74     0.5840      ------            ACID STRENGTH , PH      =   5.15
  FLYASH              -----     ------      ******            FLYASH CONC. GM/100ML   =  *****
  SOLIDS,MG           -----     ------       5.635

  COAL COMPOSITION-MASS

    CARBON      0.7150
    HYDROGEN    0.0485
    OXY+NIT     0.0817
    SULFUR      0.0370
    ASH         0.0740
    WATER       0.0438

*
*SOLIDS FREE BASIS, MASS/VOLUME SOLUTION
```

B-39

```
RUN NUMBER  13-A          DATE 9-27-71      TIME OF DAY 1600

FLUE GAS DATA    FLOW    TEMP.     SO2      NOX      NOX*1    NOX*2    HUM.    DEW     STAT
                 #/HR     F        PPM      PPM      PPM      PPM      #/#    POINT    PRES
                                                                               F      IN.WG
FURNACE EXIT    5696.   570.0   1713.5   ******   ******    674.2   0.058   116.1    -0.1
FLOAT.BED EX    3547.   132.0      8.5    580.9   ******    730.4   0.164   148.2   -14.9
NOX SCRUB IN    3466.   166.0   ******    525.8    662.5    664.8   0.164   148.2     1.4
NOX SCRUB EX    3509.   128.0   ******    580.3    256.4    725.7   0.179   152.3     0.0

NOX SCRUB.DATA TEMP. FLOW     SCRUB.PERFORMANCE        SPRAY SLURRY ANALYSIS
                F    #/MIN      SO2 ABSORB.   ******
MAKEUP WATER   60.0   0.81      NOX ABSORP.  -10.36      MGO,GM/100ML          0.975
MAKEUP MGO     60.0   2.00      NOX1 ABSORP   61.30      MGSO3(SOLID),M       0.0312
PRODUCT LIQ.  132.0   3.35      NOX2 ABSORP   -9.15      MGSO3(TOTAL),M       0.0332
RECIRC. LIQ.  132.0  1270.      GAS VEL.FPS    1.7       MGSO4,MOLAR          0.0292
                                L/G,GAL/MCF  156.2       MG(NO2)2, MOLAR      0.0106
NO2 FLOW DATA                   L/G,#/#       22.0       MG(NO3)2, MOLAR      0.0018
  NO2 FLOWRATE,#/MIN     0.03   PRES.DROP,WG   0.1       TSS,GM/100ML         11.783
  NO2/NO( PDS BASIS)    -0.09                            NITRITE/NITRATE       5.889
  NO2/NO(FC & ROTO)      0.63

MATERIAL BALANCE                                    **       MAKEUP MGO COMPOSITION
                  SULFUR  MAGNESIUM  WATER     NITROGEN         SLURRY CONC.,GM MGO/100ML=    5.80
 NOX SCRUBBER
  INPUT,#/HR       0.03      4.18     650.0      0.72
  OUTPUT,#/HR      0.40      1.54     535.0      0.86

PHYSICAL PROPERTIES OF
RECYCLED SLURRY

  PH                     8.15
  CONDUCT.MICROMHOS       397.
  SPECIFIC GRAVITY       1.025


NOX    = PDS ANALYSIS
NOX*1  = SALTSMAN ANALYSIS
NOX*2  = FUEL CELL ANALYSIS

** OXIDIZED NITROGEN CNLY
```

```
                    MAGNESIUM BASE SLURRY SCRUBBING PROGRAM-OUTPUT DATA PAGE 1

   RUN NUMBER  14-I          DATE 9-27-71     TIME OF DAY 1700

 FLUE GAS DATA             FLOW    TEMP.     SO2      SO3     NOX    FLYASH     HUM.    DEW     DRY     STAT
                           #/HR      F       PPM      PPM     PPM    GR/DSCF    #/#    POINT    FLOW    PRES
                                                                                         F      #/HR   IN.H2O
   PRIMARY AIR              474.   120.0   ------   -----   -----   -------   0.016    76.1     467.    14.9
   SECONDARY AIR           4575.   691.3   ------   -----   -----   -------   0.017    77.0    4499.     6.0
   FURNACE EXIT            5434.   590.0   1704.6   *****   *****   *******   0.058   116.2    5138.     0.0
   PART.SCRB.INLET         5434.   490.0   ******   *****   *****   *******   0.058   116.2    -----     4.1
   PART.CYC.EXIT           3311.   139.0   1587.7   *****   *****   *******   0.142   144.3    2900.    -8.1
   VENT ABS.INLET          *****  ******   ******   *****   *****   *******  ******   *****    -----   *****
   ABS CYC.EXIT            *****  ******   ******   *****   *****   *******  ******   *****    -----   *****
   FLOATING BED IN         3311.   140.0   ******   *****   *****   *******   0.142   144.3    -----    -8.1
   FLOATING BED EX         3480.     0.0   ******   *****   *****   *******   0.171   149.4    -----   -16.3
   P.P. EXIT ORIF.         3480.   133.0      2.0   *****    529.   *******   0.171   149.4    2971.   -16.3

 SCRUBBER STREAM DATA                                           VENTURI ABSORBER        FBA
   PARTICULATE             TEMP,F   FLOW,GPM     GAS ABSORBER  TEMP,F FLOW,#/M  TEMP,F  FLOW,#/M
    MAKEUP WATER            60.0      0.0          MAKEUP WATER   *****   *****      60.0     0.6
    PRODUCT LIQ.           138.0      0.0          MAKEUP MGO SL. *****     3.3       0.0     3.3
    RECIRCULATED LIQ.      138.0     19.78         PRODUCT LIQ.   *****   *****     138.0     0.0
                                                   REC.(SPRAY NOZ) *****  *****     138.0     0.0
                                                   REC.(FLOW NOZ.)        *****               3.8

 FURNACE PERFORMANCE                      SCRUBBER PERFORMANCE      PART.     VENT ABS.    FLOAT.BED
   HEAT RELEASE,BTU/HR    0.511E 07          SO2 ABSORB.EFF          6.86      ******        99.88
   %   FUEL AS COAL            96.2          FLYASH COL.EFF        ******      ******       ******
   COAL FLOW RATE,#/HR        403.8          SO3 ABSORB.EFF        ******      ******       ******
   NAT.GAS FLOW,#/HR            8.9          NOX ABSORB.EFF        ******      ******       ******
   %   EXCESS AIR              18.6          GAS VELOCITY,FPS        90.8      ******          5.9
   OXYGEN,%DRY,MEAS.           3.90          LIQ/GAS,GAL/MCF         22.0      ******          0.6
   CO2,%DRY-CALC.             14.68          LIQ/GAS,#/#              3.0      ******          0.1
   HUMIDITY,#/# - CALC.       0.058          PRES.DROP,IN.WG          2.5      ******        -15.0

SO2 ABSORPTION PARAMETERS                                              SULFATE FORMATION PARAMETERS
  VENTURI ABSORBER                FLOATING BED ABSORBER

   KGA,#MOLE/HR-FT3,     = ******   KGA,#MOLE/HR-FT3        =    41.2      CONC.,GM-MOLE/L=  ******
   SULFITE/SO2-MOL/MOL = ******   SULFITE/SO2-MOL/MOL     =    0.23      MOL% TOTAL SULF=  *****
   SUMP RESID.TIME,MIN = ******   SUMP RESID.TIME,MIN     =  ******      O2 AT FURN. EX.=   3.90
                                                                         O2 AT ABSORB.IN=  *****
 ***** MEANS ITEM NOT MEASURED                                            O2 AT ABSORB.EX=  *****
```

```
                     MAGNESIUM BASE SLURRY SCRUBBING PROGRAM - OUTPUT DATA PAGE 2

   RUN NUMBER  14-I          DATE 9-27-71     TIME OF DAY 1700

MATERIAL BALANCES                                                        INPUT FOR EQ. - KIN.PROG.
                    SULFUR   MAGNESIUM  FLYASH    WATER    DRY GAS
  FURNACE                                                                INPUT FLOWS,#ATOMS/100#FEED
    INPUT,#/HR      14.94     ------     29.88    277.8     5131.          CARBON      0.457498
    OUTPUT,#/HR      9.16     ------    ******    296.9     5138.          HYDROGEN    0.608727
                                                                           OXYGEN      1.395331
  PART.SCRUBBER                                                            NITROGEN    5.064827
    INPUT,#/HR       9.16     ------    ******     360.     5138.          SULFUR      0.008681
    OUTPUT,#/HR      4.81     ------    ******     411.     2900.
                                                                         FEED RATE,#/SEC=   1.49
  SO2 ABSORBERS
    INPUT,#/HR       4.81       5.67    ******     638.     2900.        ENTHALPY,BTU/# =   -4413.
    OUTPUT,#/HR      0.01     ******    ******     509.     2971.
*
*SO2 ABSORBERS-     GM SO2/   GM-MOLE/    GRAM/        MAKEUP MGO COMPOSITION
 PRODUCT COMP.      100ML     LITER       100ML         SLURRY CONC.- GM MGO/100ML =       4.70
                                                        MGO PRESLAKED, NO=0, YES=1           0
  TOTAL,             2.15     0.3359     ------         % SLAKED TO MG(OH)2,MEAS.  =    ******
  COMBINED           2.15     0.3359     ------
  FREE               0.0      0.0        ------        PRODUCT MG BASE PHYSICAL PROPERTIES
  MONO(TOTAL)        2.15     0.3359     ------         ACID STRENGTH, PH      =    8.10
  MONO(DISSOLVED)    0.96     0.1500      1.560         SP.GRAVITY,HYDROM.     =   *******
  MONO(SOLID)        1.19     0.1859      3.942
  BISULFITE          0.0      0.0         0.0
  MGO                3.44     0.5368      2.147
  SULFATE           *****     ******     ******        PARTICULATE SCRUBBER PRODUCT
  MAGNESIUM          5.59     0.8728     ------         ACID STRENGTH , PH     =    5.30
  FLYASH            -----     ------     ******         FLYASH CONC. GM/100ML  =   *****
  SOLIDS,MG         -----     ------     11.272

  COAL COMPOSITION-MASS

   CARBON       0.7150
   HYDROGEN     0.0485
   OXY+NIT      0.0817
   SULFUR       0.0370
   ASH          0.0740
   WATER        0.0438

*
*SOLIDS FREE BASIS, MASS/VOLUME SOLUTION
```

```
RUN NUMBER  14-I          DATE 9-27-71      TIME OF DAY 1700

FLUE GAS DATA    FLOW    TEMP.     SO2      NOX      NOX*1     NOX*2     HUM.    DEW    STAT
                 #/HR     F        PPM      PPM      PPM       PPM       #/#    POINT   PRES
                                                                                  F     IN.WG
FURNACE EXIT    5434.    590.0  1704.6   ******   ******     648.7    0.058  116.2     0.0
FLOAT.BED EX    3480.    133.0     2.0    528.6   ******     614.9    0.171  149.4   -16.3
NOX SCRUB IN    3460.    166.0  ******   1310.9    689.1    ******    0.171  149.4     1.4
NOX SCRUB EX    3502.    129.0  ******   1076.8    492.4    ******    0.186  153.5     0.0

NOX SCRUB.DATA TEMP. FLOW     SCRUB.PERFORMANCE         SPRAY SLURRY ANALYSIS
                 F    #/MIN     SO2 ABSORB.   ******
MAKEUP WATER    60.0   0.81     NOX ABSORP.    17.86       MGO,GM/100ML          3.350
MAKEUP MGO      60.0   1.20     NOX1 ABSORP    28.55       MGSO3(SOLID),M      0.0031
PRODUCT LIQ.   133.0   3.00     NOX2 ABSORP    -9.15       MGSO3(TOTAL),M      0.0041
RECIRC. LIQ.   133.0  1270.     GAS VEL.FPS     1.7        MGSO4,MOLAR         0.0185
                                L/G,GAL/MCF   155.9        MG(NO2)2, MOLAR     0.0115
NO2 FLOW DATA                   L/G,#/#        22.0        MG(NO3)2, MOLAR     0.0020
  NO2 FLOWRATE,#/MIN    0.03    PRES.DROP,WG    0.1        TSS,GM/100ML        16.356
  NO2/NO( PDS BASIS)    1.48                               NITRITE/NITRATE     5.750
  NO2/NO(FC & ROTO)     0.76

MATERIAL BALANCE                                   **       MAKEUP MGO COMPOSITION
                       SULFUR  MAGNESIUM  WATER   NITROGEN      SLURRY CONC.,GM MGO/100ML=  10.20
  NOX SCRUBBER
   INPUT,#/HR           0.01      4.41    619.1     1.77
   OUTPUT,#/HR          0.13      3.77    551.2     1.52

PHYSICAL PROPERTIES OF
RECYCLED SLURRY

   PH                    8.25
   CONDUCT.MICROMHOS      310.
   SPECIFIC GRAVITY      1.040



NOX   = PDS ANALYSIS
NOX*1 = SALTSMAN ANALYSIS
NOX*2 = FUEL CELL ANALYSIS

** OXIDIZED NITROGEN ONLY
```

```
                         MAGNESIUM BASE SLURRY SCRUBBING PROGRAM-OUTPUT DATA PAGE 1
  RUN NUMBER  15-A          DATE 9-28-71     TIME OF DAY 1325
 FLUE GAS DATA
                           FLOW    TEMP.    SO2     SO3     NOX    FLYASH     HUM.     DEW      DRY      STAT
                           #/HR     F       PPM     PPM     PPM    GR/DSCF    #/#     POINT     FLOW     PRES
                                                                                        F       #/HR    IN.H2O
   PRIMARY AIR             471.   130.0   ------  -----   -----   -------    0.018    79.4     462.     14.9
   SECONDARY AIR          4538.   687.5   ------  -----   -----   -------    0.020    81.8    4450.      5.5
   FURNACE EXIT           5396.   540.0   ------  -----   -----   -------    0.061   118.1    5085.      0.0
   PART.SCRB.INLET        5396.   440.0   1675.5  *****   *****   *******    0.061   118.1    -----      2.7
   PART.CYC.EXIT          3432.   139.0   ******  *****   *****   *******    0.134   142.6    3027.     -8.1
   VENT ABS.INLET         *****   ******  1369.9  *****   *****   *******   ******   *****    -----    *****
   ABS CYC.EXIT           *****   ******  ******  *****   *****   *******   ******   *****    -----    *****
   FLOATING BED IN        3432.   135.0   ******  *****   *****   *******    0.134   142.6    -----     -8.1
   FLOATING BED EX        3560.     0.0   ******  *****   *****   *******    0.162   147.9    -----    -14.9
   P.P. EXIT ORIF.        3560.   130.0     18.4  *****    547.   *******    0.162   147.9    3063.    -14.9
 SCRUBBER STREAM DATA
  PARTICULATE                                                     VENTURI ABSORBER         FBA
                         TEMP,F   FLOW,GPM        GAS ABSORBER    TEMP,F FLOW,#/M    TEMP,F  FLOW,#/M
   MAKEUP WATER           60.0      0.0            MAKEUP WATER    *****    *****       60.0      0.7
   PRODUCT LIQ.          136.0      0.0            MAKEUP MGO SL.  *****      3.4        0.0      3.4
   RECIRCULATED LIQ.     136.0     19.78           PRODUCT LIQ.    *****    *****      135.0      0.0
                                                   REC.(SPRAY NOZ) *****    *****      135.0      0.0
                                                   REC.(FLOW NOZ.)          *****              385.0
 FURNACE PERFORMANCE
  HEAT RELEASE,BTU/HR    0.514E 07     SCRUBBER PERFORMANCE     PART.     VENT ABS.    FLOAT.BED
  %   FUEL AS COAL          96.2        SO2 ABSORB.EFF          18.24      ******        98.66
  COAL FLOW RATE,#/HR      406.4        FLYASH COL.EFF         ******      ******       ******
  NAT.GAS FLOW,#/HR          8.9        SO3 ABSORB.EFF         ******      ******       ******
  %   EXCESS AIR            17.1        NOX ABSORB.EFF         ******      ******       ******
  OXYGEN,%DRY,MEAS.         3.60        GAS VELOCITY,FPS         93.4      ******          6.0
  CO2,%DRY-CALC.           14.94        LIQ/GAS,GAL/MCF          21.4      ******         60.6
  HUMIDITY,#/# - CALC.     0.061        LIQ/GAS,#/#               2.9      ******          6.5
                                        PRES.DROP,IN.WG           3.0      ******          7.2
SO2 ABSORPTION PARAMETERS
 VENTURI ABSORBER
                                   FLOATING BED ABSORBER                 SULFATE FORMATION PARAMETERS

  KGA,#MOLE/HR-FT3,     = ******   KGA,#MOLE/HR-FT3         =    27.4    CONC.,GM-MOLE/L=  ******
  SULFITE/SO2-MOL/MOL   = ******   SULFITE/SO2-MOL/MOL      =   22.69    MOL% TOTAL SULF=  *****
  SUMP RESID.TIME,MIN   = ******   SUMP RESID.TIME,MIN      =  ******    O2 AT FURN. EX.=   3.60
                                                                         O2 AT ABSORB.IN=  *****
 ***** MEANS ITEM NOT MEASURED                                           O2 AT ABSORB.EX=  *****
```

```
                MAGNESIUM BASE SLURRY SCRUBBING PROGRAM - OUTPUT DATA PAGE 2

   RUN NUMBER  15-A          DATE 9-28-71      TIME OF DAY 1325

 MATERIAL BALANCES                                                    INPUT FOR EQ. - KIN.PROG.
                       SULFUR    MAGNESIUM  FLYASH     WATER     DRY GAS
   FURNACE                                                            INPUT FLOWS,#ATOMS/100#FEED
     INPUT,#/HR         15.04     ------      30.07     291.5      5078.     CARBON       0.464768
     OUTPUT,#/HR         8.90     ------     ******     310.6      5085.     HYDROGEN     0.634411
                                                                             OXYGEN       1.394469
   PART.SCRUBBER                                                             NITROGEN     5.058137
     INPUT,#/HR          8.90     ------     ******      374.      5085.     SULFUR       0.008820
     OUTPUT,#/HR         4.33     ------     ******      404.      3027.
                                                                           FEED RATE,#/SEC=    1.48
   SO2 ABSORBERS
     INPUT,#/HR          4.33       5.63     ******      641.      3027.   ENTHALPY,BTU/# =    =6030.
     OUTPUT,#/HR         0.06     ******     ******      496.      3063.
 *
 *SO2 ABSORBERS-       GM SO2/   GM-MOLE/    GRAM/         MAKEUP MGO COMPOSITION
  PRODUCT COMP.        100ML     LITER       100ML           SLURRY CONC.- GM MGO/100ML =       4.60
                                                             MGO PRESLAKED, NO=0, YES=1            0
   TOTAL,               2.88     0.4495      ------          % SLAKED TO MG(OH)2,MEAS.  =     ******
   COMBINED             2.88     0.4495      ------
   FREE                 0.0      0.0         ------        PRODUCT MG BASE PHYSICAL PROPERTIES
   MONO(TOTAL)          2.88     0.4495      ------          ACID STRENGTH, PH      =    8.05
   MONO(DISSOLVED)      0.86     0.1344       1.397          SP.GRAVITY,HYDROM.     =   *******
   MONO(SOLID)          2.02     0.3151       6.680
   BISULFITE            0.0      0.0          0.0
   MGO                  3.55     0.5552       2.221
   SULFATE             *****     ******      ******        PARTICULATE SCRUBBER PRODUCT
   MAGNESIUM            6.43     1.0047      ------          ACID STRENGTH , PH     =  *****
   FLYASH              -----     ------      ******          FLYASH CONC. GM/100ML  =  *****
   SOLIDS,MG           -----     ------      11.985

   COAL COMPOSITION-MASS

     CARBON      0.7150
     HYDROGEN    0.0485
     OXY+NIT     0.0817
     SULFUR      0.0370
     ASH         0.0740
     WATER       0.0438

 *
 *SOLIDS FREE BASIS, MASS/VOLUME SOLUTION
```

B-45

```
RUN NUMBER  15-A          DATE 9-28-71     TIME OF DAY 1325

FLUE GAS DATA    FLOW     TEMP.    SO2      NOX      NOX*1     NOX*2    HUM.    DEW    STAT
                 #/HR      F       PPM      PPM      PPM       PPM      #/#     POINT  PRES
                                                                                 F     IN.WG
FURNACE EXIT     5396.    540.0  1675.5   ******   ******     785.5    0.061   118.1    0.0
FLOAT.BED EX     3560.    130.0    18.4    547.5   ******     835.8    0.162   147.9  -14.9
NOX SCRUB IN     3518.    168.0  ******    971.8    694.9     795.6    0.162   147.9    1.4
NOX SCRUB EX     3560.    128.0  ******   1136.4    471.8     845.9    0.176   152.1    0.0

NOX SCRUB.DATA TEMP. FLOW    SCRUB.PERFORMANCE          SPRAY SLURRY ANALYSIS
                F    #/MIN    SO2 ABSORB.   ******
MAKEUP WATER   60.0   0.81    NOX ABSORP.   -16.93       MGO,GM/100ML          -0.0
MAKEUP MGO     60.0   2.00    NOX1 ABSORP    32.10       MGSO3(SOLID),M        0.0
PRODUCT LIQ.  130.0   3.00    NOX2 ABSORP    -6.33       MGSO3(TOTAL),M        0.0003
RECIRC. LIQ.  130.0  1260.    GAS VEL.FPS     1.7        MGSO4,MOLAR           0.0061
                              L/G,GAL/MCF   152.8        MG(NO2)2, MOLAR       0.0082
NO2 FLOW DATA                 L/G,#/#        21.5        MG(NO3)2, MOLAR       0.0012
  NO2 FLOWRATE,#/MIN    0.04  PRES.DROP,WG    0.2        TSS,GM/100ML          12.929
  NO2/NO( PDS BASIS)    0.78                             NITRITE/NITRATE       6.833
  NO2/NO(FC & ROTO)     0.59

MATERIAL BALANCE
                                                   **
                    SULFUR  MAGNESIUM  WATER   NITROGEN     MAKEUP MGO COMPOSITION
 NOX SCRUBBER                                                 SLURRY CONC.,GM MGO/100ML=   6.20
  INPUT,#/HR         0.06     4.46     651.8     1.34
  OUTPUT,#/HR        0.04     0.07     536.5     1.62

PHYSICAL PROPERTIES OF
RECYCLED SLURRY

  PH                       8.10
  CONDUCT.MICROMHOS         208.
  SPECIFIC GRAVITY         1.040


NOX    = PDS ANALYSIS
NOX*1  = SALTSMAN ANALYSIS
NOX*2  = FUEL CELL ANALYSIS

** OXIDIZED NITROGEN ONLY
```

```
                                  MAGNESIUM BASE SLURRY SCRUBBING PROGRAM-OUTPUT DATA PAGE 1

   RUN NUMBER  16-K          DATE 9-28-71     TIME OF DAY 1500

  FLUE GAS DATA                FLOW    TEMP.     SO2     SO3     NOX    FLYASH     HUM.    DEW      DRY      STAT
                               #/HR      F       PPM     PPM     PPM   GR/DSCF     #/#    POINT     FLOW     PRES
                                                                                            F       #/HR    IN.H2O
    PRIMARY AIR                471.    130.0  ------   -----   -----   -------    0.019    80.3     462.      14.9
    SECONDARY AIR             4532.    687.5  ------   -----   -----   -------    0.019    79.9    4449.       6.1
    FURNACE EXIT              5387.    570.0  1643.2   *****   *****   *******    0.060   117.5    5083.       0.0
    PART.SCRB.INLET           5387.    460.0  ******   *****   *****   *******    0.060   117.5    -----       2.7
    PART.CYC.EXIT             2580.    139.0  ******   *****   *****   *******    0.137   143.6    2269.      -5.4
    VENT ABS.INLET            *****   ******  ******   *****   *****   *******   ******   *****    -----     *****
    ABS CYC.EXIT              *****   ******  ******   *****   *****   *******   ******   *****    -----     *****
    FLOATING BED IN           2580.    135.0  ******   *****   *****   *******    0.137   143.6    -----      -5.4
    FLOATING BED EX           2759.      0.0  ******   *****   *****   *******    0.166   148.6    -----     -14.9
    P.P. EXIT ORIF.           2759.    128.0    14.2   *****    628.   *******    0.166   148.6    2367.     -14.9

  SCRUBBER STREAM DATA                                               VENTURI ABSORBER       FBA
    PARTICULATE              TEMP,F   FLOW,GPM        GAS ABSORBER   TEMP,F FLOW,#/M   TEMP,F  FLOW,#/M
      MAKEUP WATER            60.0      0.0             MAKEUP WATER    *****   *****      60.0      0.8
      PRODUCT LIQ.           135.0      0.0             MAKEUP MGO SL.  *****     3.5       0.0      3.5
      RECIRCULATED LIQ.      135.0     19.78            PRODUCT LIQ.    *****   *****     133.0      0.0
                                                        REC.(SPRAY NOZ) *****   *****     133.0      0.0
                                                        REC.(FLOW NOZ.)         *****              385.0

  FURNACE PERFORMANCE                        SCRUBBER PERFORMANCE     PART.     VENT ABS.     FLOAT.BED
    HEAT RELEASE,BTU/HR    0.511E 07           SO2 ABSORB.EFF        ******      ******        ******
    %   FUEL AS COAL            96.2           FLYASH COL.EFF        ******      ******        ******
    COAL FLOW RATE,#/HR        403.9           SO3 ABSORB.EFF        ******      ******        ******
    NAT.GAS FLOW,#/HR            8.9           NOX ABSORB.EFF        ******      ******        ******
    %   EXCESS AIR              17.6           GAS VELOCITY,FPS        69.9      ******           4.6
    OXYGEN,%DRY,MEAS.           3.70           LIQ/GAS,GAL/MCF         28.5      ******          78.0
    CO2,%DRY-CALC.             14.86           LIQ/GAS,#/#              3.8      ******           8.4
    HUMIDITY,#/# - CALC.       0.060           PRES.DROP,IN.WG          1.6      ******          15.7

 SO2 ABSORPTION PARAMETERS                                                 SULFATE FORMATION PARAMETERS
   VENTURI ABSORBER                  FLOATING BED ABSORBER
                                                                             CONC.,GM-MOLE/L=  ******
    KGA,#MOLE/HR-FT3,     = ******    KGA,#MOLE/HR-FT3        = ******       MOL% TOTAL SULF=  *****
    SULFITE/SO2-MOL/MOL   = ******    SULFITE/SO2-MOL/MOL     = ******       O2 AT FURN. EX.=   3.70
    SUMP RESID.TIME,MIN   = ******    SUMP RESID.TIME,MIN     = ******       O2 AT ABSORB.IN=  *****
                                                                             O2 AT ABSORB.EX=  *****
    ***** MEANS ITEM NOT MEASURED
```

```
              MAGNESIUM BASE SLURRY SCRUBBING PROGRAM - OUTPUT DATA PAGE 2
  RUN NUMBER  16-K          DATE 9-28-71     TIME OF DAY 1500
MATERIAL BALANCES
                     SULFUR   MAGNESIUM  FLYASH    WATER    DRY GAS        INPUT FOR EQ. - KIN.PROG.
  FURNACE
     INPUT,#/HR       14.94    ------     29.89     285.6     5076.        INPUT FLOWS,#ATOMS/100#FEED
     OUTPUT,#/HR       8.73    ------    ******     304.7     5083.          CARBON        0.462322
                                                                             HYDROGEN      0.637765
  PART.SCRUBBER                                                              OXYGEN        1.394753
     INPUT,#/HR        8.73    ------    ******                              NITROGEN      5.060390
     OUTPUT,#/HR     ******    ------    ******     368.      5083.          SULFUR        0.008773
                                                    311.      2269.
  SO2 ABSORBERS                                                             FEED RATE,#/SEC=    1.48
     INPUT,#/HR      ******      5.80    ******
     OUTPUT,#/HR       0.04    ******    ******     560.      2269.         ENTHALPY,BTU/# =    -5495.
*                                                   392.      236'.
*SO2 ABSORBERS-      GM SO2/   GM-MOLE/    GRAM/           MAKEUP MGO COMPOSITION
 PRODUCT COMP.       100ML     LITER       100ML            SLURRY CONC.- GM MGO/100ML =       4.60
                                                            MGO PRESLAKED, NO=0, YES=1            0
   TOTAL,             2.91     0.4540      ------           % SLAKED TO MG(OH)2,MEAS.  =     ******
   COMBINED           2.91     0.4540      ------
   FREE               0.0      0.0         ------          PRODUCT MG BASE PHYSICAL PROPERTIES
   MONO(TOTAL)        2.91     0.4540      ------           ACID STRENGTH, PH       =     8.10
   MONO(DISSOLVED)   -2.70     -.4219      -4.387           SP.GRAVITY,HYDROM.     =   *******
   MONO(SOLID)        5.61     0.8759      18.569
   BISULFITE          2.64     0.2062       3.836
   MGO                3.81     0.5955       2.382
   SULFATE           *****     ******      ******          PARTICULATE SCRUBBER PRODUCT
   MAGNESIUM          6.72     1.0495      ------           ACID STRENGTH , PH      =   *****
   FLYASH            -----     ------      ******           FLYASH CONC. GM/100ML   =   *****
   SOLIDS,MG         -----     ------      11.253

  COAL COMPUSITION-MASS

   CARBON        0.7150
   HYDROGEN      0.0485
   OXY+NIT       0.0817
   SULFUR        0.0370
   ASH           0.0740
   WATER         0.0438

*SOLIDS FREE BASIS, MASS/VCLUME SOLUTION
```

B-48

```
RUN NUMBER  16-K          DATE 9-28-71      TIME OF DAY 1500

FLUE GAS DATA    FLOW    TEMP.     SO2      NOX      NOX*1    NOX*2    HUM.     DEW     STAT
                 #/HR     F        PPM      PPM      PPM      PPM      #/#     POINT    PRES
                                                                                F      IN.WG
FURNACE EXIT    5387.    570.0   1643.2   ******   ******    715.7   0.060   117.5     0.0
FLOAT.BED EX    2759.    128.0     14.2    627.7   ******    403.2   0.166   148.6   -14.9
NOX SCRUB IN    2726.    166.0   ******    866.3    642.5    846.8   0.166   148.6     1.4
NOX SCRUB EX    2763.    128.0   ******    886.4    449.4    514.1   0.182   153.0     0.0

NOX SCRUB.DATA TEMP. FLOW     SCRUB.PERFORMANCE       SPRAY SLURRY ANALYSIS
                 F     #/MIN    SO2 ABSORB.  ******
MAKEUP WATER    60.0   0.81     NOX ABSORP.   -2.32      MGO,GM/100ML       -0.0
MAKEUP MGO      60.0   1.20     NOX1 ABSORP   30.06      MGSO3(SOLID),M     0.0
PRODUCT LIQ.   130.0   3.00     NOX2 ABSORP   39.29      MGSO3(TOTAL),M     0.0
RECIRC. LIQ.   130.0   800.     GAS VEL.FPS    1.3       MGSO4,MOLAR        0.0047
                                L/G,GAL/MCF  125.3       MG(NO2)2, MOLAR    0.0138
NO2 FLOW DATA                   L/G,#/#       17.6       MG(NO3)2, MOLAR    0.0023
  NO2 FLOWRATE,#/MIN    0.02    PRES.DROP,WG   0.2       TSS,GM/100ML        9.047
  NO2/NO( PDS BASIS)    0.38                             NITRITE/NITRATE    6.000
  NO2/NO(FC & ROTO)     0.92

MATERIAL BALANCE                                   **     MAKEUP MGO COMPOSITION
                    SULFUR  MAGNESIUM  WATER   NITROGEN      SLURRY CONC.,GM MGO/100ML=   6.20
 NOX SCRUBBER
  INPUT,#/HR        0.04      2.68     503.9     0.93
  OUTPUT,#/HR       0.03      0.09     427.6     1.03

PHYSICAL PROPERTIES OF
RECYCLED SLURRY

  PH                    8.15
  CONDUCT.MICROMHOS      340.
  SPECIFIC GRAVITY      1.038



NOX   = PDS ANALYSIS
NOX*1 = SALTSMAN ANALYSIS
NOX*2 = FUEL CELL ANALYSIS

** OXIDIZED NITROGEN ONLY
```

```
                          MAGNESIUM BASE SLURRY SCRUBBING PROGRAM-OUTPUT DATA PAGE 1
 RUN NUMBER  17-J         DATE 9-28-71     TIME OF DAY 1600

FLUE GAS DATA            FLOW    TEMP.    SO2     SO3     NOX    FLYASH     HUM.     DEW      DRY      STAT
                         #/HR      F      PPM     PPM     PPM    GR/DSCF    #/#     POINT     FLOW     PRES
  PRIMARY AIR            472.    130.0  ------   -----   -----   -------                F     #/HR    IN.H2O
  SECONDARY AIR         4537.    690.0  ------   -----   -----   -------    0.018    78.7      463.     16.3
  FURNACE EXIT          5395.    580.0  1951.5   *****   -----   -------    0.021    83.1     4445.      6.1
  PART.SCRB.INLET       5395.    475.0  ******   *****   *****   *******    0.062   118.6     5081.      0.0
  PART.CYC.EXIT         3373.    138.0  1692.4   *****   *****   *******    0.062   118.6     -----      2.7
  VENT ABS.INLET        *****   ******  ******   *****   *****   *******    0.143   144.7     2951.     -8.1
  ABS CYC.EXIT          *****   ******  ******   *****   *****   *******   ******   *****     -----    *****
  FLOATING BED IN       3373.    132.0  ******   *****   *****   *******   ******   *****     -----    *****
  FLOATING BED EX       3495.      0.0  ******   *****   *****   *******    0.143   144.7     -----     -8.1
  P.P. EXIT ORIF.       3495.    130.0    18.9   *****    577.   *******    0.171   149.4     -----    -16.3
                                                                            0.171   149.4     2986.    -16.3
SCRUBBER STREAM DATA                                                VENTURI ABSORBER        FBA
  PARTICULATE            TEMP,F   FLOW,GPM       GAS ABSORBER      TEMP,F FLOW,#/M  TEMP,F  FLOW,#/M
   MAKEUP WATER           60.0      0.0           MAKEUP WATER      *****    *****     60.0      0.8
   PRODUCT LIQ.          137.0      0.0           MAKEUP MGO SL.    *****      3.2      0.0      3.2
   RECIRCULATED LIQ.     137.0     19.78          PRODUCT LIQ.      *****    *****    137.0      0.0
                                                  REC.(SPRAY NOZ)   *****    *****    137.0      0.0
                                                  REC.(FLOW NOZ.)            *****             385.0
FURNACE PERFORMANCE
  HEAT RELEASE,BTU/HR     C.514E 07     SCRUBBER PERFORMANCE      PART.     VENT ABS.     FLOAT.BED
  %   FUEL AS COAL             96.1       SO2 ABSORB.EFF          13.28      ******          98.88
  COAL FLOW RATE,#/HR         405.9       FLYASH COL.EFF         ******      ******         ******
  NAT.GAS FLOW,#/HR             9.0       SO3 ABSORB.EFF         ******      ******         ******
  %   EXCESS AIR               17.1       NOX ABSORB.EFF         ******      ******         ******
  OXYGEN,%DRY,MEAS.            3.60       GAS VELOCITY,FPS         92.1      ******         ******
  CO2,%DRY-CALC.              14.94       LIQ/GAS,GAL/MCF          21.7      ******            5.9
  HUMIDITY,#/# - CALC.        0.062       LIQ/GAS,#/#               2.9      ******           61.2
                                          PRES.DROP,IN.WG           2.8      ******            6.6
                                                                                               8.6
SO2 ABSORPTION PARAMETERS
  VENTURI ABSORBER                                                        SULFATE FORMATION PARAMETERS
                                   FLOATING BED ABSORBER

  KGA,#MOLE/HR-FT3,     = ******   KGA,#MOLE/HR-FT3         =    27.8      CONC.,GM-MOLE/L=  ******
  SULFITE/SO2-MOL/MOL   = ******   SULFITE/SO2-MOL/MOL      =    1.31      MOL % TOTAL SULF=  *****
  SUMP RESID.TIME,MIN   = ******   SUMP RESID.TIME,MIN      =  ******      O2 AT FURN. EX.=   3.60
                                                                           O2 AT ABSORB.IN=  *****
 ***** MEANS ITEM NOT MEASURED                                             O2 AT ABSORB.EX=  *****
```

```
              MAGNESIUM BASE SLURRY SCRUBBING PROGRAM - OUTPUT DATA PAGE 2

    RUN NUMBER  17-J          DATE 9-28-71      TIME OF DAY 1600

MATERIAL BALANCES                                                         INPUT FOR EQ. - KIN.PROG.
                         SULFUR    MAGNESIUM  FLYASH    WATER     DRY GAS
  FURNACE                                                                 INPUT FLOWS,#ATOMS/100#FEED
    INPUT,#/HR           15.02     ------      30.03    295.1     5074.     CARBON      0.464699
    OUTPUT,#/HR          10.36     ------     ******    314.4     5081.     HYDROGEN    0.629736
                                                                            OXYGEN      1.394463
  PART.SCRUBBER                                                             NITROGEN    5.058205
    INPUT,#/HR           10.36     ------     ******    377.      5081.     SULFUR      0.008817
    OUTPUT,#/HR           5.22     ------     ******    422.      2951.
                                                                           FEED RATE,#/SEC=   1.48
  SO2 ABSORBERS
    INPUT,#/HR            5.22       5.38     ******    656.      2951.    ENTHALPY,BTU/# =   -6372.
    OUTPUT,#/HR           0.06     ******     ******    509.      2986.
*
*SO2 ABSORBERS-          GM SO2/   GM-MOLE/    GRAM/          MAKEUP MGO COMPOSITION
 PRODUCT COMP.           100ML     LITER       100ML            SLURRY CONC.- GM MGO/100ML =      4.60
                                                                MGO PRESLAKED, NO=0, YES=1           0
  TOTAL,                  2.86     0.4474      ------           % SLAKED TO MG(OH)2,MEAS.  =    ******
  COMBINED                2.86     0.4474      ------
  FREE                    0.0      0.0         ------         PRODUCT MG BASE PHYSICAL PROPERTIES
  MONO(TOTAL)             2.86     0.4474      ------           ACID STRENGTH, PH      =    8.05
  MONO(DISSOLVED)         0.06     0.0094       0.097           SP.GRAVITY,HYDROM.     =   *******
  MONO(SOLID)             2.80     0.4380       9.286
  BISULFITE               0.0      0.0          0.0
  MGO                     3.85     0.6020       2.408
  SULFATE                *****     ******      ******         PARTICULATE SCRUBBER PRODUCT
  MAGNESIUM               6.72     1.0494      ------           ACID STRENGTH , PH     =   5.25
  FLYASH                 -----     ------      ******           FLYASH CONC. GM/100ML  =  *****
  SOLIDS,MG              -----     ------      11.264

  COAL COMPOSITION-MASS

    CARBON      0.7150
    HYDROGEN    0.0485
    OXY+NIT     0.0817
    SULFUR      0.0370
    ASH         0.0740
    WATER       0.0438

*
*SOLIDS FREE BASIS, MASS/VOLUME SOLUTION
```

```
RUN NUMBER  17-J         DATE 9-28-71     TIME OF DAY 1600

FLUE GAS DATA    FLOW    TEMP.    SO2     NOX     NOX*1     NOX*2    HUM.    DEW     STAT
                 #/HR     F       PPM     PPM     PPM       PPM      #/#     POINT   PRES
                                                                              F      IN.WG
FURNACE EXIT     5395.   580.0  1951.5  ******  ******     815.7    0.062   118.6     0.0
FLOAT.BED EX     3495.   130.0    18.9   576.6  ******     704.9    0.171   149.4     0.0
NOX SCRUB IN     3466.   166.0  ******  1194.6   609.6     856.0    0.171   149.4   -16.3
NOX SCRUB EX     3503.   129.0  ******  1223.1   451.1     916.4    0.183   153.2     0.0

NOX SCRUB.DATA TEMP. FLOW    SCRUB.PERFORMANCE       SPRAY SLURRY ANALYSIS
                 F   #/MIN    SO2 ABSORB.  ******
MAKEUP WATER   60.0   C.81    NOX ABSORP.   -2.38    MGO,GM/100ML        -0.0
MAKEUP MGO     60.0   0.85    NOX1 ABSORP   25.99    MGSO3(SOLID),M       0.0
PRODUCT LIQ.  130.0   2.15    NOX2 ABSORP   -7.06    MGSO3(TOTAL),M       0.0
RECIRC. LIQ.  130.0  1260.    GAS VEL.FPS    1.7     MGSO4,MOLAR          0.0056
                              L/G,GAL/MCF  155.0     MG(NO2)2, MOLAR      0.0215
NO2 FLOW DATA                 L/G,#/#       21.8     MG(NO3)2, MOLAR      0.0046
  NO2 FLOWRATE,#/MIN   0.04   PRES.DROP,WG   0.2     TSS,GM/100ML        20.148
  NO2/NO( PDS BASIS)   1.07                          NITRITE/NITRATE      4.674
  NC2/NO(FC & ROTO)    0.70

MATERIAL BALANCE                                  **     MAKEUP MGO COMPOSITION
                     SULFUR  MAGNESIUM  WATER  NITROGEN     SLURRY CONC.,GM MGO/100ML=  13.80
 NOX SCRUBBER
  INPUT,#/HR          0.06     4.22     597.6    1.62
  OUTPUT,#/HR         0.02     0.10     544.6    1.75

PHYSICAL PROPERTIES OF
RECYCLED SLURRY

  PH                   8.50
  CONDUCT.MICROMHOS     321.
  SPECIFIC GRAVITY     1.042


NOX   = PDS ANALYSIS
NOX*1 = SALTSMAN ANALYSIS
NOX*2 = FUEL CELL ANALYSIS

** OXIDIZED NITROGEN ONLY
```